DISCOVERY

Monthly Notebook

British Atomic Energy Bill
Comparison with U.S. Bill
Modified Gramicidin
The Arditron
Radar and Meteors

Horseflies
HAROLD OLDROYD, M.A., F.R.E.S.

Chemical Stimulants for Crops
RICHARD CLEMENTS, B.Sc., F.L.S.

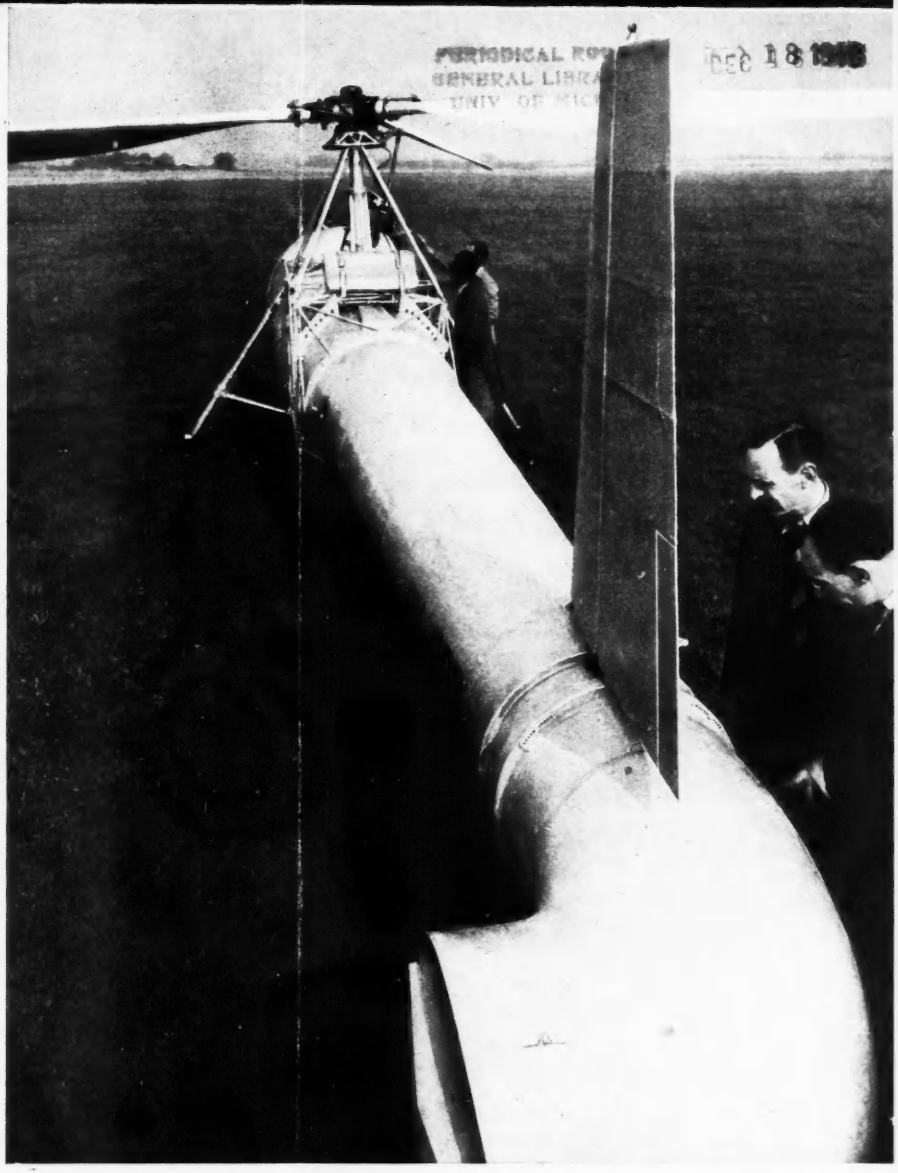
Can Prediction become a Science?
S. LILLEY, Ph.D.

Low-temperature Physics
K. MENDELSSOHN, M.A., Ph.D.

Two Aircraft Engineering Films

Bookshelf

Far and Near



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The *Measurement of Dielectric Loss—*

by the

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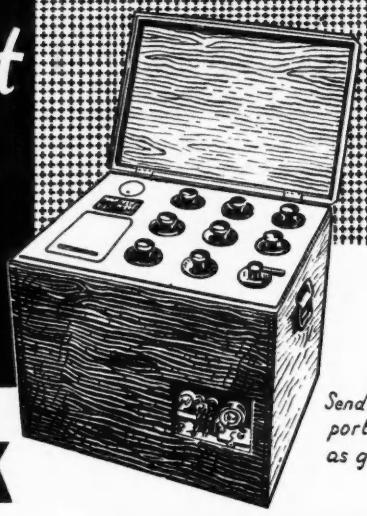

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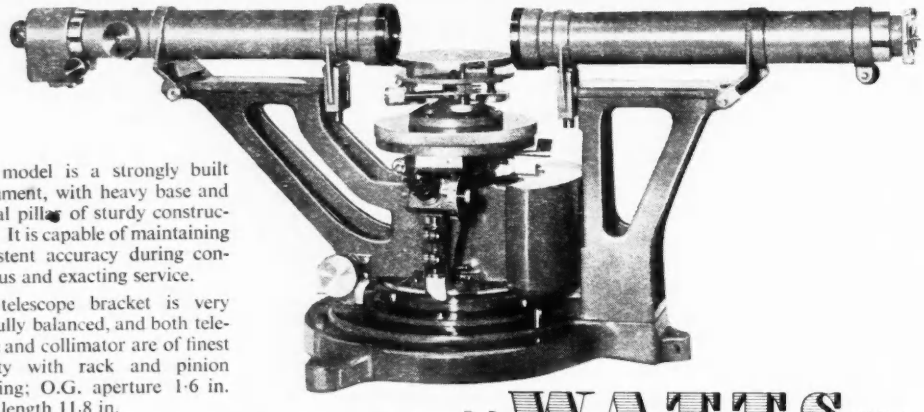

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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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The Progress of Science

Atomic Energy Bill

A SUBSTANTIAL measure of scientific freedom disappeared between October 8 and October 11 when the House of Commons passed the Atomic Bill, including Clause 11—the security clause—which was accepted virtually without modification.

As the *Observer* so rightly said, when scientists started research on atomic bombs they took a path which was bound to lead away from the free scientific world in which knowledge knew no frontiers, a path which in the absence of international control of atomic energy was bound to lead into "a strange murky country of guarded laboratories, secrecy regulations and spy scares." Some loss of freedom was certainly inevitable in the particular circumstances. The Government spokesmen maintain that the best possible compromise so far as security is concerned is the one they have made, a point of view with which many scientists probably agree though a large number have expressed a different view. The freedom that has been lost cannot be regained until a strong practical system of international control has been worked out and put into effective operation. How long that will take will depend upon the speed with which the constituent members of UNO recognise reality and accept the necessity of surrendering a part of national sovereignty to the greater safety of themselves and of the world.

Anybody who attended the debates or read the full reports in Hansard will have been amazed at the rather casual way in which this very important Bill passed through the House. The total time spent on the second and third readings and two committee stages was under ten hours. The attendance was very meagre. As one member put it "this is just the kind of Bill governments smuggle through on a Friday afternoon hoping nobody will understand its true import." According to the *New Statesman* the House had made up its mind that atomic energy was a dreary theme which should be drearily debated. Criticism on the more vital issues came only from a few back-bench members.

The Minister of Supply, Mr. Wilmot, appeared to have no difficulty in persuading the House to adopt his amendments but almost all other amendments were rejected or withdrawn after almost plaintive appeals from the Minister to accept his assurance that he would play the game—"I trust my words will bind my successors as much as they will bind me." The number of such assurances which he gave reached double figures and it is a little surprising that the Minister was never pressed to include in black and white as part of the Bill the assurances which he was so ready to give verbally.

One Government amendment was highly commended to the House by both the Prime Minister and the Minister of Supply as generally extending the things that should be exempt from restriction under Clause 11. This adds a new subsection requiring that: "The Minister shall not withhold consent" for publication "if he is satisfied that the information proposed to be communicated is not of importance for purposes of defence." One cannot help wondering if there is now any piece of nuclear physics of which one could feel satisfied that it would be unimportant for defence. The implications of discoveries are rarely so accurately foreseeable that one can be sure whether or not they will have potential military value. Mr. Blackburn pointed out the cautiousness of the double negative in the amendment, but when he pressed the Minister on this point he had to be content with another assurance from Mr. Wilmot that "he will interpret this in such a way that, if possible, he will free the information, and that he will only decide not to free it if he is absolutely satisfied it is reasonably likely to contribute to the production of weapons of destruction."

Critics of the Bill raised the point made in *Discovery* about its extremely negative attitude. The negative aspect emerges very clearly from the Table comparing the British and American Atomic Energy Bills.

In the House of Lords on October 23, Lord Cherwell, in a speech far better informed than any that came from the other House, made much of this point. He deplored the dearth of detail concerning the Minister's own constructive activities in the atomic energy field: he confessed his uneasiness at finding so much "stress laid upon the powers

	U.S. Atomic Energy Act	*British Atomic Energy Bill*
AIMS	Assisting and fostering private research and development to encourage maximum scientific progress. Dissemination of scientific and technical information to encourage scientific progress and sharing of information reciprocally *re* industrial application as soon as destructive uses are controlled. Government research and development; government control of production, ownership and use of fissionable materials for defence and development; to fit into international policy of U.S. Government.	To promote development of atomic energy. To control unauthorised use or production of atomic energy and publication of certain information.
RESPONSIBLE OFFICIALS	Atomic Energy Commission (5 full-time members) appointed by President—5-year terms of office, salaries $15,000 a year (chairman $17,000). +General Manager, to discharge administrative and executive functions, appointed by President on recommendation of Commission.	Minister of Supply.
ORGANISATION	Division of Research Division of Production Division of Engineering Division of Military Application	
ADVISORY COMMITTEES	General Advisory Committee on scientific and technical matters, relating to materials, production, research and development. 9 members, all civilians. Appointments for 6 years, must meet at least 4 times yearly. Commission may establish further Advisory Boards.	
RELATIONS WITH MILITARY	Military Liaison Committee of representatives of Army and Navy. Atomic Energy Commission shall advise and consult with Committee on all atomic energy matters which the Committee deems to relate to military applications. Commission authorised to conduct experiments, research and development in military application of atomic energy and to produce atomic bombs to extent of express consent and direction of President; consent and direction must be obtained once a year at least. Unlawful for anyone to manufacture or possess atomic bomb except under authorisation of of Commission. Director of Division of Military Application shall be member of Armed Forces.	
RESEARCH outside Commission or Ministry	Commission is directed to exercise its powers in such a manner as to ensure the continued conduct and development by private and public scientific institutions in all atomic energy fields. May make contracts, agreements and loans for research without regard to competitive bidding regulations governing ordinary Government contracts; must provide for health protection and inspecting. Must not restrict dissemination of scientific or technical information except to extent already provided by law.	Minister may make grants or loans to any person engaged in production or use of atomic energy or research into relevant matters. Minister may make available under licence fissionable materials and plant necessary for research
RESEARCH by Commission or Ministry	Commission authorised and directed to carry on research in all above fields.	Minister empowered to conduct research on production and use of atomic energy.
PRODUCTION OF FISSIONABLE MATERIALS (ownership of production-facilities)	Commission shall be sole government owner of all government interests in fissionable materials and atomic weapons, processes, patents, atomic energy contracts, etc. Commission exclusively to own all facilities for production of fissionable materials except those useful for research and development in specified fields, and which do not have capacity to enable operator to produce fissionable material sufficient for atomic bomb in reasonable time. Commission must produce fissionable materials; may do so by contracts with non-government persons or institutions in government-owned plants. Contractors must submit to inspection.	Minister may take over any existing contract relating to production of atomic energy. Minister has power to manufacture, produce, buy, acquire, store or transport any articles likely to be used in production or use of atomic energy. Minister has power to acquire compulsorily any plant designed or adapted for production or use of atomic energy or research into matters connected therewith, on just compensation.

	U.S. Atomic Energy Act	*British Atomic Energy Bill*
AMOUNT OF FISSIONABLE MATERIALS TO BE PRODUCED	Determined annually by President.	
CONTROL OF FISSIONABLE MATERIALS	All fissionable material to be property of Commission. Private owners to be compensated. Possession may be retained by owner on authorisation of Commission; title belongs to Commission.	All fissionable material (prescribed substance) to be acquired, possessed, used, exported or imported under licence from Minister. Fissionable materials may be produced only under licence from Minister.
ATOMIC MINERALS	Except under licence, no one may transfer or own or export atomic minerals once mined. (This does not apply to negligible quantities). Commission authorised to require reports of ownership on atomic minerals. U.S. reserves for own use all atomic minerals in public lands. Commission may acquire possession on just compensation.	Minister authorised to acquire possession of of atomic minerals on just compensation.
ATOMIC MINERAL SURVEY	Commission authorised to explore directly or by contract for atomic minerals.	Minister authorised to conduct surveys of atomic minerals.
CONTROL OF BY-PRODUCT MATERIALS	Commission authorised to distribute free or with charge radioactive by-products for research or development. No by-product materials may be distributed by Commission to foreign governments, persons outside U.S. Govt. jurisdiction or persons in U.S.A. who might be dangerous to U.S. security.	Minister may make by-product materials available under licence for research and education or for commercial purposes not involving the production or use of atomic energy.
INDUSTRIAL AND COMMERCIAL PRODUCTION AND USE OF ATOMIC ENERGY	Neither atomic energy, nor atomic energy equipment can be produced, owned or exported without the Commission's licence. Where industrial or commercial use of atomic energy has developed to practical level, Commission shall report to President on social, political, economic and international significance and recommend supplementary legislation. No licence to be issued until 90 days after such a report to Congress; thereafter unless prohibited by law, Commission is directed to issue licences on non-exclusive basis and supply appropriate amounts of fissionable materials to licencees.	
INTERNATIONAL RELATIONS	Any clause of this Act is ineffective insofar as it conflicts with any international arrangements made afterwards. Commission must give maximum effect to any international arrangements hereafter approved by U.S. Government.	
CONTROL OF INFORMATION	Dissemination of scientific and technical information about atomic energy should be permitted and encouraged, consonant with national security. Until Congress declares that there are adequate international controls over atomic weapons, no information shall be exchanged with other nations concerning industrial use of atomic energy. Restricted data shall include all data on the manufacture or use of atomic weapons, production of fissionable material or use of fissionable material in production of power. Penalty for communication of restricted information with intent to give an advantage to a foreign nation: not more than $20,000 or 20 years' imprisonment. Where there is intent to injure the U.S.A., a jury may sentence to death or life-imprisonment.	Any persons communicating information about plant being used or intended to be used for producing or using atomic energy shall be punished on summary conviction by not more than 3 months' imprisonment or £100 fine; on indictment, not more than 5 years or £500. The Minister may grant exemptions from this restriction in certain cases.

the Minister has to prevent other people working freely on this topic and how little stress is laid upon the methods he shall use to promote research and development." Lord Cherwell then went on to make clear how Treasury and Civil Service Control would render atomic energy development almost impossible, and he underlined the necessity of short-circuiting usual time-wasting, bureaucratic procedure.

Mr. Ranger made a good speech dealing with international control aspects but one feels that this speech would have had greater effect—it would certainly have had a bigger audience—in a foreign policy debate.

The second line of opposition dealt with the effects of this secrecy on scientists and on the progress of science. As Mr. Errol put it, the clause "may in fact become a sort of iron curtain between our scientists and the true fundamental nature of matter."

There is the further danger, not mentioned in the debate

at all that the clause will divide scientists into two classes: those who obtain full information through a restricted circulation of reports and those who try to carry on without this advantage. Any scientist who has worked under similar conditions in wartime, when such restrictions are necessary, will realise how much inefficiency this division may lead to.

Some attempt was made to render the operation of the Bill a little less reminiscent of 'Pooh-Bah', and an amendment asking for an advisory council to be set up to advise the Minister. This council was to be nominated by the Minister himself, not elected by Parliament or any other body. Yet this was turned down by Mr. Wilmot on the grounds, first, that an advisory council would be a shield behind which a Minister could hide when criticised in Parliament, and second, that its existence would prevent him from seeking advice in wider circles. But Mr. Wilmot did offer an assurance that he would take lots of advice.

Effective parliamentary criticism of any action the Minister takes, or fails to take, over atomic energy seems to be rendered difficult by the fact that the secrecy provisions make it almost impossible for an M.P. to acquire the necessary information without a breach of Clause 11.

An amendment requiring the Minister to report periodically on licences issued for projects involving the use of prescribed materials that would otherwise be the Minister's monopoly was uncompromisingly turned down. To the general question of how Parliament was to exert control, Mr. Wilmot could only reply that if something went wrong, "the people concerned would ask the Minister for permission to communicate with the Members of Parliament and, supposing the Minister were so short-sighted, foolish and mean as to use his powers under this Bill to refuse permission, I ask the Committee how long could that Minister last?" In other words, in cases of desperation there is a hope of control but only through extremely radical action involving, at the minimum, a motion of censure upon the Minister, provided some Member can convince the House merely on the denial of information that something is very seriously wrong!

A dozen back-benchers put up a plucky fight—though we might have wished that occasionally they had not withdrawn so readily. But they had virtually no success although several of them convinced themselves that they had done the opposite, judging from the self-congratulatory letter that appeared in *The Times*. Only minor concessions, in fact, were made.

The speeches of those who fought for the amelioration of the Bill in the House of Commons all too often showed (and we say this with all respect) a deficiency of knowledge about science and scientific organisation. One would have wished that there was one M.P. like Prof. A. V. Hill to do justice to the subject under discussion. Some blame for such shortcomings must rest with the scientists themselves for not briefing adequately their Parliamentary allies.

Modified Gramicidin

FOR the past two or three years gramicidin, an antibiotic produced by a species of soil bacteria known as *Bacillus brevis*, has been produced commercially in the United States. It has powerful antibacterial properties, chiefly against the so-called Gram-positive bacteria* such as staphylococci and streptococci (responsible for septicæmia), but it is also poisonous to tissues of the body. A lesser disadvantage is that it is very sparingly soluble in water. For these reasons its clinical use is limited, though it has been quite widely used in veterinary work, particularly for treating mastitis in cows.

During the past year, however, simple derivatives of gramicidin have been prepared which retain the high antibacterial activity of the original gramicidin but lack most of its toxicity. The improvement is striking enough to make it probable that the importance of gramicidin in medicine may grow very quickly during the next few months.

The first results were published in September 1945 by research workers at the Western Regional Research Laboratory, California. They reported that on treatment with formaldehyde gramicidin was converted without loss into a derivative, known as methylol gramicidin, which could be easily isolated in the form of a powder. Methylol gramicidin was found to be about half as active against the standard test bacteria, *Staphylococcus aureus*, as gramicidin itself. Part at least of the toxicity of gramicidin is due to the fact that it destroys the red blood corpuscles; in this respect methylol gramicidin was found to be only one-tenth as destructive. Tests with rats showed that the over all toxicity of methylol gramicidin was very strikingly less than that of the gramicidin. Finally, methylol gramicidin was found to be four times as soluble as gramicidin.

These results were so promising that the work has been continued, with results even more encouraging. If methylol gramicidin is further treated with succinic acid an important new derivative is formed. In this the antibacterial activity is reduced fourfold but at the same time the toxicity is reduced fifty-fold. The derivative is also more soluble, so that the net result is a drug with greatly improved therapeutic properties.

By reversing the order of treatment—using first succinic acid and then formaldehyde—yet another useful derivative is formed. This has three-quarters of the antibacterial activity of gramicidin, four times its solubility, and a greatly reduced toxicity. Treatment of gramicidin with succinic acid alone gives another derivative with improved properties.

Although these derivatives of gramicidin do not in general possess the same range of antibacterial activity and clinical advantages as penicillin there is, nevertheless, a very urgent need for such drugs in treating specific infections. Even among bacterial species which are normally highly sensitive in penicillin there occur a few strains which have a natural resistance to it. Resistance may also be acquired during treatment. These penicillin-resistant strains may be quite as dangerous as the ordinary strains, and it is therefore essential to have an alternative to fall back on, even if the alternative drug has not quite such ideal properties as penicillin.

* The distinction between Gram-positive and Gram-negative bacteria, now recognised as reflecting a fundamental biochemical difference, was discovered in 1884 by the Danish bacteriologist, Christian Gram. Gram-positive bacteria hold stains of the pararosaniline series (e.g. gentian violet) after treatment with iodine and alcohol; Gram-negative bacteria are decolorised in this test, the alcohol removing the stain. Bacteria sensitive to penicillin are nearly always Gram-positive.

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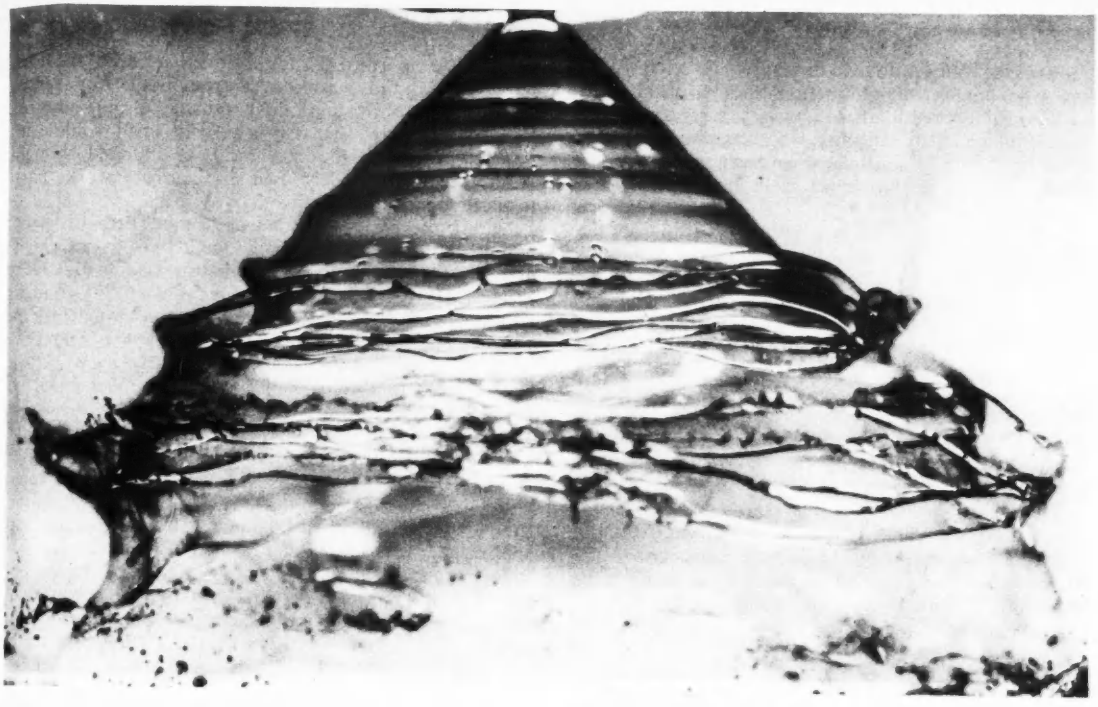
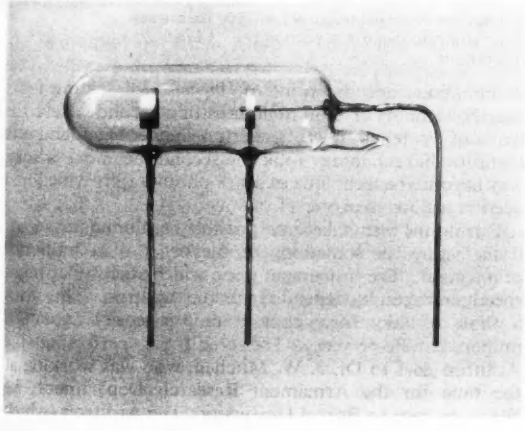
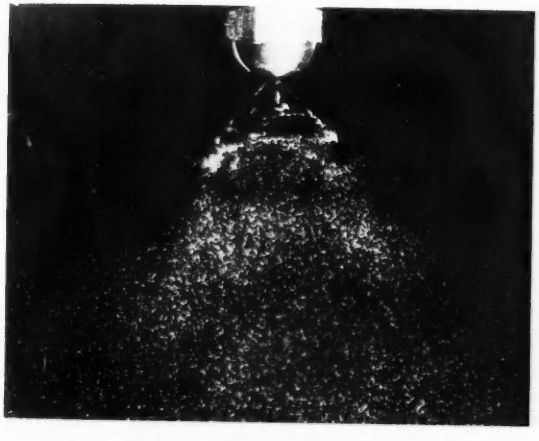


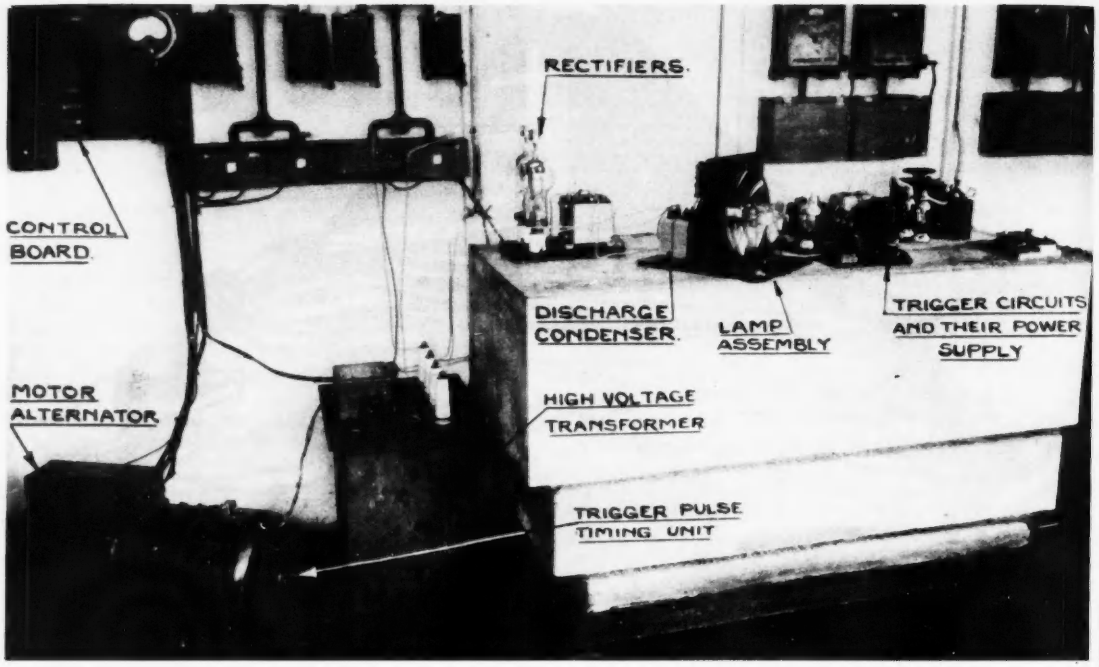




Top photograph shows the hollow cone formed by fuel sprayed through a minaret jet. Water has been substituted for fuel in taking this ultra high-speed photograph with the aid of the Arditron tube. *Bottom left*, the Arditron tube. One of the electrodes is ring shaped, and surrounds a rod-shaped electrode. *Right*, the third electrode is a ring. The discharge is confined to a very narrow channel close to the tube's axis. *Bottom right*, this Arditron photograph shows the atomisation of fuel by a minaret jet. (*Arditron photograph by Mullard; the jet pictures by courtesy of M.O.S.*)

The Arditron

A GREAT many technical problems that had to be solved during the war were problems requiring high-speed photography capable of analysing a sequence of events that takes an extremely short period of time for its completion. Two methods of high-speed photography were available for studying such problems as projectiles in flight and at the moment of impact, the behaviour of the gas bubble produced in under-water explosions and the kind of spray pattern produced by fuel injectors. One was cinematography, and here improvements have led to the development of high-speed cine cameras operating at speeds up to 8000 frames a second. Here intermittent illumination is achieved by means of the camera shutter. In the other method the film is exposed all the time and



This apparatus using Arditrons to take a succession of photographs at a fixed frequency of 1000 flashes per second was developed at the Admiralty Undex Works for studying explosion phenomena. (*Admiralty photograph, Crown copyright.*)

Here an Arditron is set into a searchlight reflector. The beam is concentrated in front of the muzzle of a gun so that photographs can be taken of a shell just after it has left the muzzle.

illumination depends on intense flashes each lasting for a few thousandths or even millionths of a second. Here the work of Professor H. E. Edgerton at the Massachusetts Institute of Technology took the second technique a long way beyond the technique of spark photography which had been in use for many years.

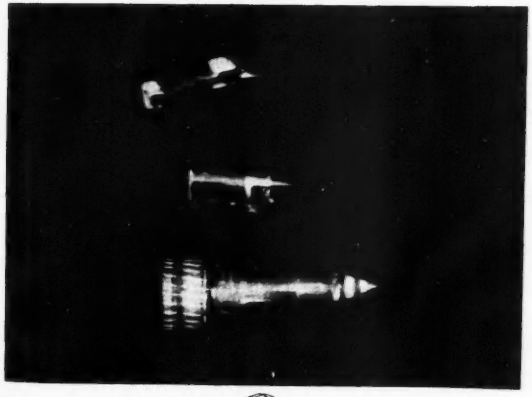
During the war it became possible to illuminate with a flash lasting for something of the order of a millionth of a second. The instrument upon which such super high-speed photography depended was the Arditron. This gives a flash of very high photographic intensity (about a million candle-power). The credit for perfecting the Arditron goes to Dr. J. W. Mitchell, who was working at the time for the Armament Research Department; he has since gone to Bristol University. The Arditron (which incorporates in its name the initials of the Armament Research Department) is a gas discharge tube containing an inert gas mixture. The kind of flash and its duration depend on a number of facts, including the nature of gases filling the tube and also their pressure; argon at atmospheric pressure is an example of a typical gas filling. A discharge of the order of 7000 volts takes place extremely rapidly through the discharge tube. The intensity of the flash is high enough for really good pictures to be obtained at objects as far as 15 ft. away from the discharge tube without the use of reflectors.

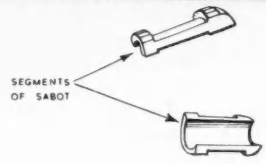
Radar and Meteors

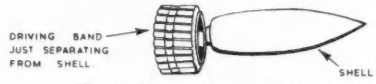
THE technique of using radar echoes to locate celestial bodies was applied last month to the detection of the

The shell from the gun makes contact with a trip-wire which actuates the camera shutter. Shells travelling at 3-4000 feet per second can be photographed in flight.

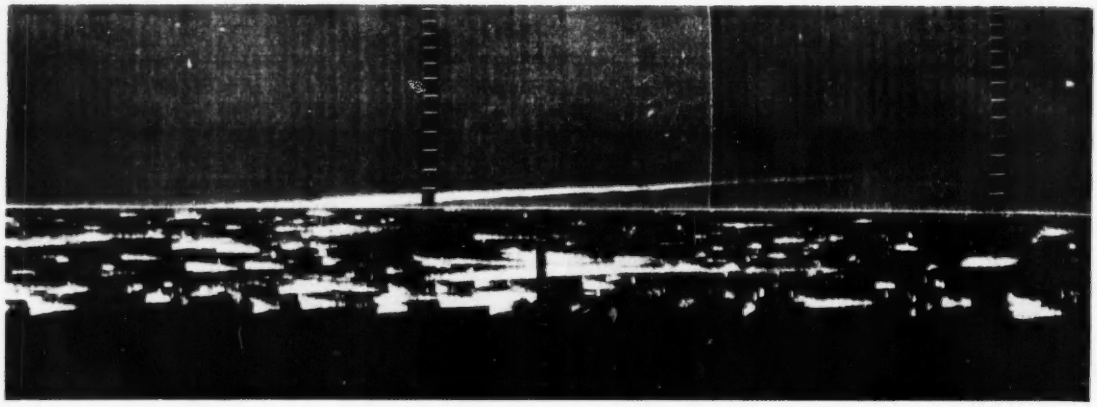
An armour-piercing 6-pounder shell is about to be fired into the 'studio', where the shell is photographed after hitting an armour-plate target.







The Arditron facilitated the development of the new type of high-velocity projectile known as the discarding sabot projectile. The penetration of this shell depends on a core of tungsten carbide, which is protected at impact by a steel sheath. The core cracks during its passage through the armour-plate and the resulting fragments have a devastating effect inside a tank. This shell has a calibre smaller than that of the gun from which it is fired. In firing, the projectile is held centrally in a sheath made up of three segments. The driving-band itself fits on to a peg on the projectile. In the photograph and diagram on left the sabot segments and driving-band are shown separating from the shell. In the photograph on the right the steel sheath is splitting off to reveal the tungsten carbide core; the streaks are due to fragments of hot metal. (*Ministry of Supply photographs.*)



Direct photographic records of cathode-ray traces due to radar echoes from meteor trails, made by Mr. R. Naismith at the Radar Research Station, Slough, on the night of October 9–10. The exposure given was ten minutes. *At top*: record made about three hours before midnight, at which time there were few meteors. *Below*: record made about four hours after midnight, when the number of meteors reached a maximum. The depth of each record corresponds to a distance of 60 miles.

meteor showers produced by the Giacobini-Zinner comet as it swept through the sky on the orbit it completes once every six and a half years. On the night of October 9 the meteor shower was due and, in addition to telescopes, radar instruments swung into action to pick up the meteors. Both in Britain and the United States radar watch was kept.

In some parts of America astronomers were lucky enough to get a good view of the meteors, and they counted as many as seventeen a minute. Dr. Harlow Shapley described the meteor display as "the richest show we've had in this century." In most parts of Britain the night was cloudy and disappointing for visual observers. But good records were obtained by the Radio Research Station of the Department of Scientific and Industrial Research at Slough and by the Army Operational Research Group in Richmond Park. Photographic records were taken at both places.

The use of radar for such a purpose dates back to the experiments of Sir Edward Appleton and Mr. R. Naismith, who noticed some curious radio echoes of very short duration coming back occasionally from reflecting objects in the atmosphere about sixty miles above ground level. These transient reflecting centres were detected using the now well-known pulse method upon which radiolocation depends. It was also noted that these very brief echoes, lasting only for a second or so, were observed both by day and night, and it was concluded that they could not be due to any solar agency.

THIS ATOMIC AGE

Ownership of the moon looms as a political problem of the future. Already the French, discussing an impending landing by space ship, say: "The first party on the moon could plant a flag and claim all of it, for there is no water cutting it up into continents." This is incorrect, diplomatically and geographically. By modern procedure, land discovered must be occupied and effectively administered.—"*Londoner's Diary*", *Evening Standard*.

Since those days evidence has accumulated showing fairly conclusively that many of the temporary reflecting phenomena in the sky are the trails of meteors. Many examples have been noted of the simultaneous occurrence of the radar echo and the glowing meteor streak in the sky.

A meteor is seen when a quite small body—often no larger than a pea—enters the earth's atmosphere from outer space and becomes white-hot through friction with the air. The radar reflection is obtained from the tubular streak of incandescent ionised gas that trails behind the meteor and not from the small solid body which causes it. It would be quite impossible at present to detect a body the size of a pea at a distance of sixty miles.

During the war similar phenomena were observed on long-range radar equipment. Dr. J. S. Hey and G. S. Stewart using British Army radar equipment working on wavelengths of about five metres have made a complete study of the reflections. Their observations show that the echoes have all the expected characteristics of reflections from meteor streaks, the maximum numbers occurring at the time of big meteor showers. They have shown how, using radar observations alone, it is possible to deduce the direction in which the meteor streams are travelling. (An interesting note about this work appears in *Nature* of October 5, 1946, on p. 481. Maximum numbers of echoes coincided with the Quadrantid meteor showers of January 3 and the Lyrids of April 20–22. The radar equipment used was pulse transmitters with Yagi aerials, operating on wavelengths of 4–5 metres at 150 kw. peak power.)

Sir Edward Appleton and Mr. Naismith have also continued their study of these phenomena, working at the Radio Research Station with a very powerful pulse transmitter and an aerial designed to radiate vertically upwards on a wavelength of eleven metres. These experiments have been proceeding for over two years and many photographic records of meteor echoes have been obtained.

At the end of the war in Europe, when there was no longer any need to continue the watch for enemy planes, many R.A.F. long-range radar stations helped in the observation of echoes from meteors.

Horseflies

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HORSEFLIES, *clegs*, *stouts*, *breeze-flies*, *dun-flies*, *serut-flies*, *gadflies*, *mooseflies*, *deerflies*, *bulldogs*, *earflies*, *pineflies*, *mangrove-flies*, *greenheads*, *thunderflies*—any group of insects which can earn such a selection of popular names must be both widespread and able to make its presence known, yet how many non-entomologists have any precise knowledge of the habits and relationships of the pests?

As might be expected, since some of the popular names are very old and of local origin, they have been misapplied to insects which modern entomologists place in different groups. The very old name of 'gad-fly' is based on a misapprehension. The insect known as *Tabanus* by Varro, the 'gad-fly' and the 'breeze' of the English translators of Homer, was a biting fly which settled on the cattle and drew blood, but it did not make the cattle 'gad'—that is, rush madly about with neck outstretched and tail held high. The belief that cattle gad because flies bite them is of long standing, but modern evidence fixes this particular disturbance on another culprit, the warble-fly, *Hypoderma bovis*, which terrorises, but does not bite.

What then are the horseflies, and why are they so widely, if locally, known? The family Tabanidae belongs to the order Diptera, the two-winged, or true flies. There are some three thousand species in the world, and many people will be surprised to learn that besides the common cleg, that furtive little pest of the English meadows, there are twenty-seven species found in Britain. Some of these are confined to the southern counties, but others are found even in the Highlands.

The general appearance of the common cleg, *Haematopota pluvialis*, is probably well known to most people, especially those who live or take their holiday in low-lying or wet parts of the country. It is a grey insect of stout build, about one-third to one-half inch in length, its most obvious features being its wings, which are speckled grey and white, and its eyes, which together occupy almost the whole of its head. In life the eyes are spectacularly marked with shining metallic blue or green tints, and wavy brown lines—a bizarre effect which, unfortunately, fades quickly after death. Another feature one soon discovers is a proboscis which seems to be well adapted for piercing the human skin and sucking blood.

These structures are common to all the Tabanidae, except the speckled wings, which are confined to the genus *Haematopota* (admirably named, from the Greek, the 'drinker of blood'). The *deerflies*, or *thunderflies* of the genus *Chrysops*, of a similar size to the clegs, are much more brightly coloured in yellow and black, with wings boldly marked in brown. Their eyes are even more dazzling than those of the cleg, with brilliant spots of purple and blue. These two genera have each four British species, the other twenty British horseflies belonging to the genus *Tabanus*, 'horseflies' in the strict sense. In these the wings are clear and unmarked, except for a brownish tinge towards the root, and the eyes are less strikingly coloured, though many species have one or more dark bands cutting across the metallic sheen. Many of the species are small, though bulkier than *Chrysops* and *Haematopota*, but one or two are giants of their kind. The three largest species, *T. sudeticus*, *T. bovinus*, and *T. verralli* may range up to one inch in length, and are the bulkiest, if not the longest, British flies (Fig. 1). They are, incidentally, as big as any horseflies known.

More Deadly than the Male

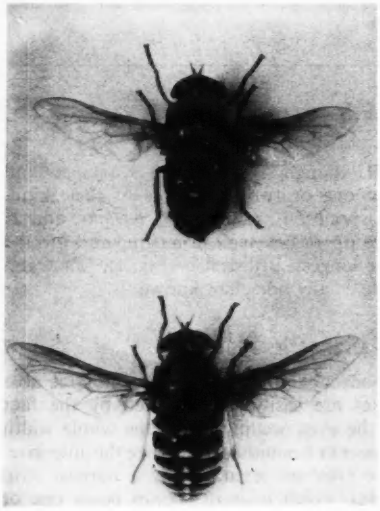
As in most bloodsucking flies, the female alone is able to bite. The sexes are easily distinguished by the fact that in the male the eyes occupy almost the whole width of the head, and meet in the middle line above the antennae. In the female the eyes are separated by a narrow strip known as the *frons*, which in most species bears one or more bare, shiny areas known as *frontal calli*. These are of great help in identifying the species, so obviously if horseflies are preserved for naming, great care must be taken not to damage these and other surface markings by excessive handling.

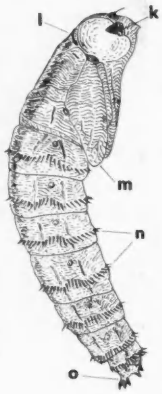
The biting equipment of the horsefly is seen in Figs. 4, 5. It will be seen that the term 'biting equipment' is inaccurate. The fly has no means of biting or chewing, but can only pierce and suck. Fig. 4 shows the head of a cleg in side view, the frons and frontal calli being partly visible (*p*, *q*).

The *labium*, or 'proboscis' proper, takes no part in biting, but is folded back out of the way. Its principal function is that of a sheath for the piercing organs, but the fleshy labella (*b*) are pierced by a number of minute tubes, known as *pseudotracheae*, and when the other organs are ensheathed the complete proboscis can be used for sucking up liquids. Male Tabanidae, which lack the piercing mandibles, cannot suck blood, and are wholly dependent on what they can absorb through the labella. They are believed, on somewhat scanty evidence, to feed from flowers.

Some of the horseflies of the genus *Pangonius*, not found in Britain, have the labium strikingly elongate. *Pangonius longirostris* from the Himalayas has a proboscis about two inches long, quite two-and-a-half times the length of the fly's body. This is believed to be used for feeding from a flower of a corresponding depth, and the fact that both sexes have an equally long labium suggests that the females, too, may take periodical meals of nectar. The long labium is certainly not used for piercing, and when biting, the female of this species, like the others, folds back the labium and uses her stylets. These are strong and workmanlike, but not abnormally long. There are horseflies with all lengths of proboscis between this extreme and one barely long enough to ensheath the stylets; the labium and the stylets may be looked upon as supplementary rather than complementary feeding organs.

In corroboration of this are Cameron's observations, published in 1934, on the feeding habits of adult clegs in the laboratory. He fed both males and females on a lump of cane-sugar, and describes how they fed like a house-fly by pressing the labella against the surface of the sugar,





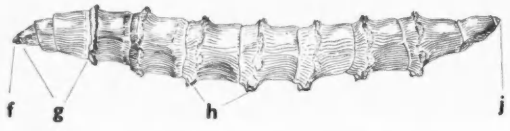


FIG. 1 (*top left*).—*Tabanus sudeticus*, the largest British horsefly, life-size. Male above, female below. FIG. 2 (*top right*).—Pupa of *T. bisignatus*, a common British horsefly: *k*, antenna; *m*, wings with traces of veins appearing; *l*, prothoracic spiracle; *n*, abdominal segments with rings of spines; *o*, anal processes. FIG. 3 (*below*).—*Tabanus* larva; *f*, head; *g*, three segments of thorax; *h*, abdominal segments with false legs; *j*, anal siphon.

moistening it with saliva, and sucking up the syrup thus formed. By staining the sugar with carmine he was able to trace the passage of the stain into the gut of the insect. Female clegs were kept alive for as much as 30 days on sugar alone, and males up to 12 days.

Cameron's work and the observations of other workers indicate that the function of the blood meal in Tabanidae is to provide nitrogenous compounds, especially proteins, which are necessary for the development of the eggs. Hence the fact that only females need to suck blood. A meal of blood is taken after fertilisation and before oviposition can begin. For this reason clegs and other horseflies caught in the field, unless they were in process of attacking when captured, cannot usually be induced to bite. If they had already been fertilised they would usually have been the first aggressor! A striking exception is the N. American horsefly *Goniops chrysocoma*, which Schwardt was unable to feed in the laboratory and which does not appear to feed during adult life. He believes that the necessary proteins are stored during larval life, as happens in botflies (Oestridae) and certain other flies.

Mating of Tabanidae has rarely been seen, but the evidence seems to be that it occurs on the wing. A number of observers have seen male horseflies dancing in a swarm, often high above the ground, and Cameron on one occasion saw a mixed swarm in which mating was taking place. After mating the female looks for a victim and takes a meal before oviposition, the average interval between the two events in captivity being six to twelve days.

Eggs of Tabanidae are not very often seen in nature. They have been found on the stems of plants in or near water or swampy ground, though sometimes in dry localities, or even in sand on the seashore. They are stacked in a neat mass, sometimes in two layers and left to hatch for a period depending on the temperature, and ranging from four to twelve days. Again the American *Goniops chrysocoma* is remarkable and apparently unique, in brooding its eggs. The female, having laid her eggs on the underside of a leaf, squats down upon them and remains there until they hatch, the fly shortly afterwards dying. The effect of this peculiar habit is not clear. The fly intermittently vibrates its wings in a way that suggests a possible form of temperature-control, but when the fly was forcibly removed the eggs developed normally.

A larvae of a horsefly is shown in Fig. 3. It is a legless grub and when well developed can easily be recognised by its small but distinct head and the circlets of *pseudopods* or fleshy protuberances which are found on the seven middle segments of the body. Under a lens or microscope the surface of the skin is seen to be shagreened, or scored in longitudinal grooves somewhat like a microscopic form of corduroy.

When first hatched the larvae are gregarious, those from one egg-mass hatching simultaneously and packing themselves tightly together. So long as their supply of yolk lasts they do not feed, but as soon as this is exhausted they become highly predacious, with a taste for cannibalism, so in their mutual interests they scatter. They feed rapaciously on any soft-bodied organism they can catch, and will tackle blowfly maggots as big as themselves,

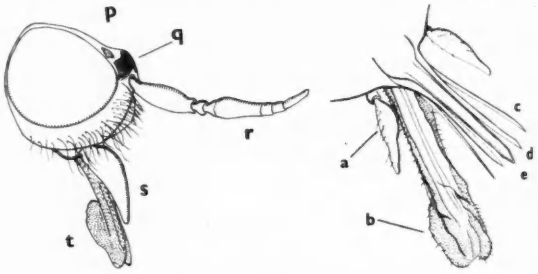


FIG. 4 (*left*).—Head of a cleg (*Haematopota pluvialis*) in side view: *r*, antenna; *s*, palp; *t*, proboscis with labella; *p*, frons; *q*, frontal callus. FIG. 5 (*right*).—Proboscis of *Chrysops* dissected to show piercing mouth-parts: *a*, palp; *b*, labella; *c*, maxilla; *d*, mandible; *e*, labrum with epipharynx and hypopharynx underneath. The labrum together with the hypopharynx and epipharynx which lies underneath, forms a pair of tubes through one of which the saliva is ejected; blood is sucked up the other. Alongside the labrum lie two pairs of slender stylets—the mandibles which are curved and swordlike, and the maxillae which bear minute teeth near their tips. When the fly bites the whole bunch of stylets is pushed through the skin and saliva is injected into the wound to prevent coagulation of blood in and around the insects' mouth-parts.

not always with success. Philip (1931) has given a number of detailed observations of the feeding-habits of horsefly larvae, and has some slight evidence that they may be able to immobilise their victims by a form of toxic injection.

In nature the larvae live in damp soil, wet sand, or damp, rotting wood, but have occasionally been found in relatively dry, mountainous areas. The British *Tabanus glaucopis* is found mostly on chalk downs above 200-300 feet, but little is known of its breeding habits. Larvae of *Chrysops* may live free in the water, and only take to the mud when they are ready to pupate. They feed on any prey they encounter, and in this connexion may be mentioned a peculiar organ known as Graber's organ which is located in the last segment of the body. This appears to be some form of gland which periodically is seen to contain black, rod-like bodies. Its function is highly problematical, but some workers claim that it is a form of auditory mechanism comparable to a primitive ear for detecting vibration. Obviously such an organ would be of immense value to a larva which depends for its food on happening to meet suitable victims while wandering through the soil.

It is as larvae that horseflies pass the winter, and in the spring or summer they take up a position near the surface and form a pupa or chrysalis. Sometimes, however, a larva may hibernate for a second winter, and not become adult until the third year of its life. A puparium of *T. bisignatus* is shown in Fig. 2. This stage lasts for ten to thirty days and then the fly emerges by splitting the puparium longitudinally along the back.

After emergence the fly remains dormant for perhaps an hour while the wings are expanding and drying and the thoracic plates are hardening sufficiently to take the pull of the flight muscles. In the Pyrenees I found over thirty horseflies of the species *T. apricus* which seemed to be nearing the end of this period of dormancy and were resting on a clump of hogweed. They could fly if sufficiently provoked, but very ineptly, and if roughly brushed off the plant they fell to the ground and had to struggle into an upright position before being able to fly away. Both sexes were present but females were in the majority.

Many records have been made of the habits of adult horseflies, particularly females in their search for a blood meal. In this country the cleg, *Haematopota pluvialis*, is the commonest species, though few non-specialists would claim to be able to distinguish it from the other three British species of the genus. The haunts of the adults follow closely the suitability of the site for egg-laying and clegs are especially troublesome in wet meadows, boggy waste ground, and muddy farm lanes. They are notorious for their silent approach, and often a fierce bite on the wrist is the first sign of one of them. At such a moment a cleg looks particularly sinister with its sombre, speckled grey colouring, and its evil-looking eyes. The deerfly, *Chrysops*, gives more warning, and usually whistles round one's head and past the ears with a high-pitched hum.

These two genera are fairly conservative in their attacks on human beings, *Haematopota* attacking about waist-high and awaiting an opportunity to settle on the wrists, *Chrysops* taking an unfair advantage by alighting on the back of the neck. The various species of *Tabanus* in Britain seem generally to prefer the legs.

Clegs in particular can be a great nuisance to agricultural workers and holiday-makers, and even to sailors!

FIG. 6.—A mountain stream near Gavarnie in the Pyrenees, a type of locality in which horseflies occur.

In an account of the hazards of small-boat sailing in the Western Isles, which I read recently, the author several times mentions being becalmed just off shore and at the mercy of clegs. H. P. Jones (1920) recorded that he was so severely bitten just above the eyes by *Chrysops* that for several days he was unable to see, and some people find that the bite of a cleg takes a long time to heal. Susceptibility to the bites of horseflies seems to vary very greatly between individuals.

C. B. Philip claims that in the State of Minnesota flies of the genus *Tabanus* seem not to like human blood, but he admits this is not so in other States, and I have never found *Tabanus* backward in investigating a human host. The business-like approach of a *Tabanus*, circling her victim with a low-pitched hum, is very distinctive, and a quick swing round with a net will usually catch her. In the British Isles the southern counties naturally have the widest choice of species to offer, but the number of individuals depends on local suitability rather than on latitude. Areas in the north can be as heavily infested as any in the country. Nor are only the small species found there. *T. bovinus*, the species typical of the entire family, is actually a rare insect, and is mostly to be found in the few remaining remnants of primeval waste land, such as the New Forest and parts of Norfolk, but the other big species, *T. sudeticus* and *T. verralli* are locally numerous in parts of Scotland and Wales.

It is, however, as pests of stock that horseflies are of most economic importance. As early as the eighteenth

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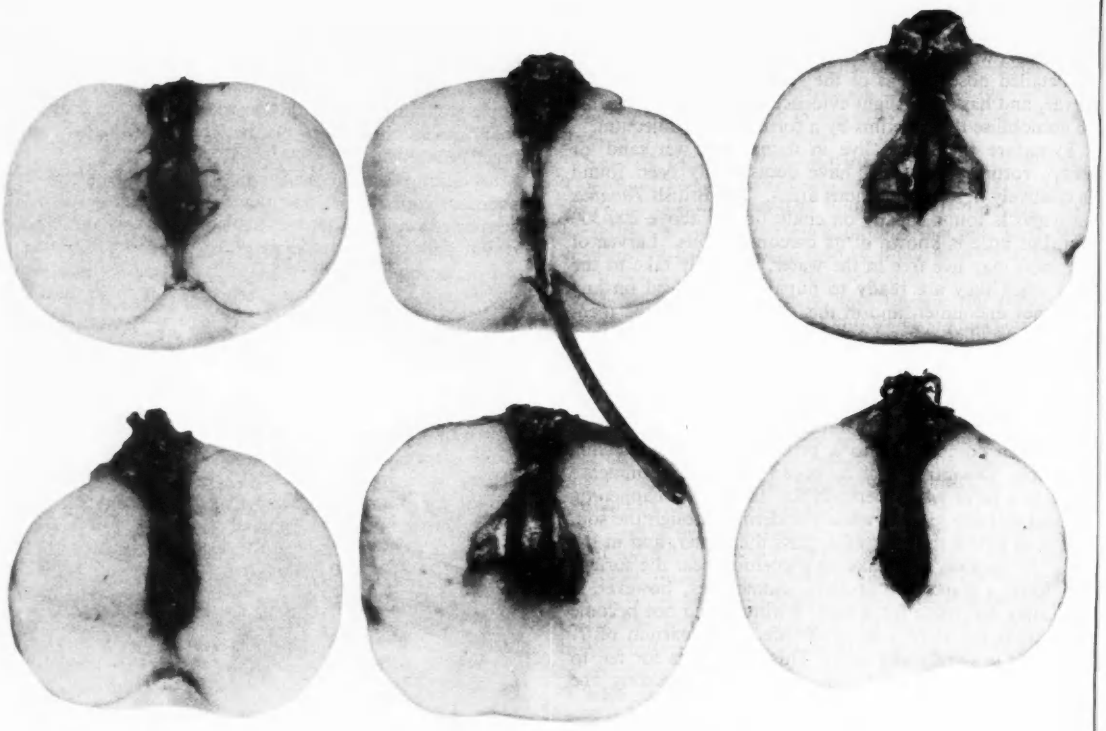


FIG. 1.—Showing Miller's Seedling Apples artificially set by hormone treatment.

Chemical Stimulants for Crops

PRACTICAL APPLICATIONS OF GROWTH-REGULATING SUBSTANCES

RICHARD CLEMENTS, B.Sc., F.L.S.

THE science dealing with growth-regulating substances of plants has made great progress during the years, and one of the experimenters in this field has thought it worth informing the public of what is going on, even though many fragments of these researches are only in their preliminary stages. The scientist who has taken this step, and with every justification in my opinion, is Dr. T. Swarbrick of the Long Ashton Research Station of Bristol University.*

Although Charles Darwin postulated the possible existence of growth-regulating substances in his book *Power of Movement in Plants*, published in 1880, it was not until 1906 that Professor E. Starling described certain substances which affected the physiology of animals. He called them hormones. Since then vitamins and other substances have been found which profoundly affect growth and development in animals and plants.

These substances, some of which are not produced directly by plants or animals themselves, and are thus not hormones, having no general name are commonly referred to as growth-regulating substances (though the term 'synthetic hormone' is used by animal physiologists). A characteristic of them is that the activity they promote bears no relation to their concentration. Minute amounts can cause major activities. Large amounts can kill, or cause opposite effects to those brought about by smaller amounts. Growth-regulating substances have been extracted from animal or plant tissues, but the majority have been synthesised in laboratories. They may initiate, inhibit or accelerate growth activities such as flower-bud formation or root development.

With the aid of these substances scientists have already discovered how to:

(1) prevent the normal pre-harvest drop of apples and pears;
(2) promote root formation in cuttings of 'difficult' plants such as shrubs and conifers;
(3) induce fruit formation from sterile flowers;
(4) prevent dropping of fruit after severe frosting;
(5) retard flower-bud development so that trees do not flower until danger of frost is over;
(6) selectively kill weeds among cereal crops.

* See *Harnessing the Hormone: The Use of Growth-Regulating Substances in Gardens, Fields and Orchards.* By Dr. T. Swarbrick (London, 1946, Grower Publications, pp. 52, 8 plates, 3s. 6d.)

It can be seen that all these applications are very important to horticulturists, agriculturists, fruit-growers —and, in the long run, even to politicians. The first three and the last one are already being applied to commercial use, while (4) and (5), especially important to British fruit-growers, are being intensively worked on.

The first practical use of growth-regulating substance was made in 1929 when a heat-resistant substance extracted from germinating barley was applied to plant cuttings, causing them to root quickly and freely. From then on the story is one of experimentation with an ever-increasing number of substances affecting almost every phase of growth, development and reproduction.

It is now known that there are over fifty substances which can regulate or control the growth and development of plants in different ways from the organic foods such as sugars, fats, etc., or inorganic manures such as nitrates, phosphates and potash. They vary from the simple gas ethylene used to ripen bananas, pears and tomatoes, to much more complex substances such as dibenzanthracene, acenaphthene and colchicine, which affect cell division and reproduction in both plants and animals. These substances are remarkable both for their specificity and for the infinitesimal quantities which are necessary to cause major changes in plants. They have a very small effective 'concentration range', outside of which effects vary from negligible, if below the concentration range, to deadly if above. The highest concentration used is 100 parts per million, and the lowest is one part in one hundred million—equivalent to one pound of the substance in 40,000 tons of water. Many have a concentration range of 10–20 p.p.m.

One of the most important losses to fruit-growers has been the pre-harvest fruit drop—the 'June drop'. Special cells at the base of the flower stalks if stimulated into activity change the constituents of the cell wall to form a weak spot—the abscission layer—so that the fruit falls off under its own weight. Drought, oil, copper and sulphur sprays, as well as various insect pests, cause premature fruit drop by stimulation of the cells of the abscission layer. The fact that certain growth-regulating substances have the opposite effect was noticed by American workers in 1934, when they were investigating the effect of α-naphthyl-acetic acid on cuttings. It was seen that those treated with this chemical not only rooted freely, but retained their leaves, whereas cuttings treated with other substances rooted but lost their foliage within a few days. The acid had apparently prevented the development of an abscission layer. The practical implications of this were at once seen and trials on fruit-trees began.

Many substances have been experimented with to prevent fruit drop, but only α-naphthyl-acetic acid and its derivatives have proved consistently effective. A 90% drop of Beauty of Bath apple was reduced to 20% by a single, well-timed application of a wash containing 10 p.p.m. of α-naphthyl-acetic acid. Not only is fruit drop prevented, but the fruit sticks to the tree so strongly that high winds cannot tear it off; sometimes indeed the pickers cannot do their job without damage to the fruit spur.

The acid is five times as effective when applied to the stalk of the apple as when put on the calyx end. But there is some natural means of transmitting the substance from the calyx to the stalk, and this raises the question of how far it can be transmitted, and whether leaves can be used as collecting centres for the stimulus. Some varieties of apple respond more readily to the pre-harvest drop spray than others, but most of the common English apples react normally.

α-Naphthyl-acetic acid and other substances also promote root formation. Since 1920 this branch of the science has received more attention than any other phase of the work. Practical development began in 1929, when a substance obtained from germinating barley was found capable of inducing rooting when it was incorporated in lanolin and applied to cuttings.

Phenyl and indole compounds are naturally occurring root-promoting substances. The best synthetic root-promoting product is derived from the relatively inert and inactive phenoxy-acetic acid, which is rendered highly active by introducing chlorine, bromine or iodine into the ring. The root-promoting effect is much greater in the higher homologues; e.g. 2 : 4-dichloro-phenoxy-propionic acid is thirty times more effective for some purposes than 2 : 4-dichloro-phenoxy-acetic acid.

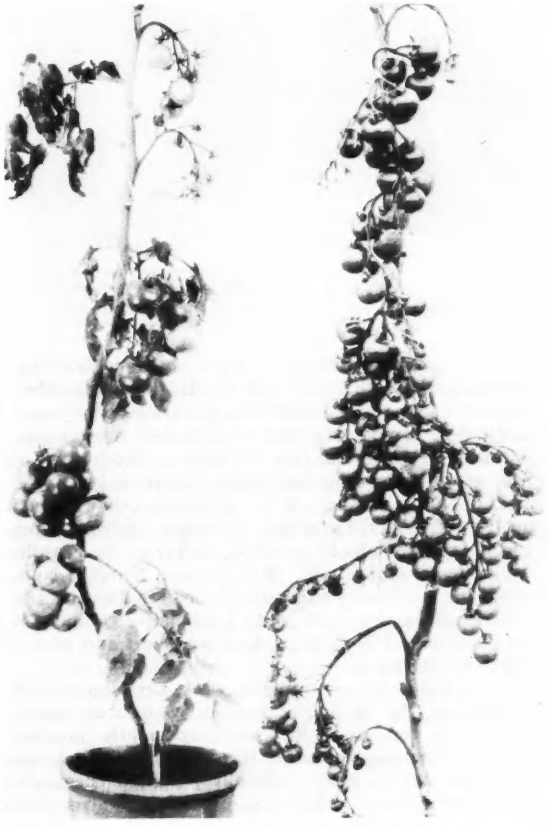


FIG. 2.—(*Left.*) Three trusses all at the same stage of development. The fourth truss was not treated and failed to develop. The fifth truss was treated. (*Right.*) A 'Jack' or sterile tomato plant, with almost every flower turned into fruit after one spray treatment.

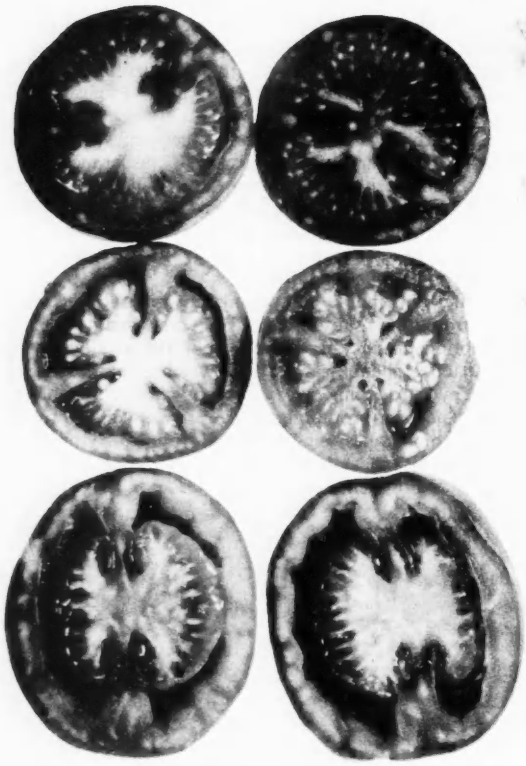


FIG. 3.—Tomatoes cut open. The top one was produced by β-naphthoxy-acetic acid, the centre one grew in the normal way, and the bottom one was produced 2 : 4-dichloro-phenoxy-acetic acid.

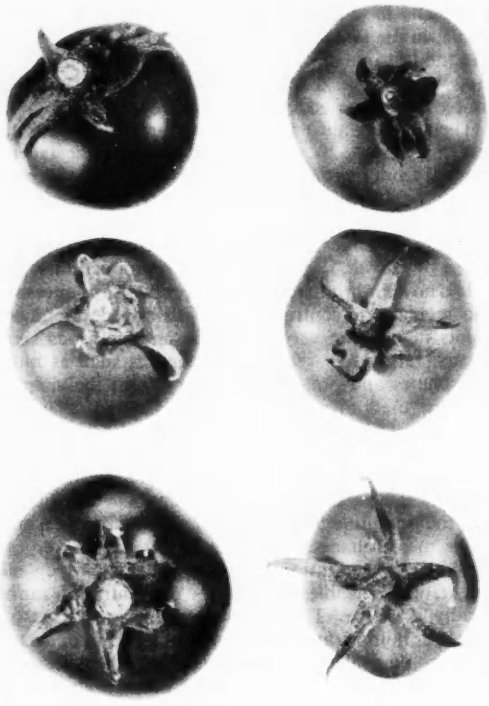


FIG. 4.—Note the thick stems and strong 'abscission layers' of the left row of fruit. The thickness is achieved by spraying with α-naphthyl-acetic acid and prevents fruit from being blown off before it is ripe.

Over a wide range of plants the dibromo- and dichloro-propionic acids were from twenty to fifty times more effective in promoting root growth than the indole, phenyl and naphthalene compounds. But the latter have a wider concentration range so that they are easier to use. Many of these growth-promoting substances exercise a synergistic effect upon one another, i.e. the substance exhibits much greater activity in the presence of another. Different types of roots can be induced at will according to the growth-regulating substance used. With the aid of indole compounds the roots are white, opaque, small in diameter and longer than the roots induced by naphthalene compounds which are relatively large in diameter, short and with a slight pinkish tinge.

Coincident with root formation work, were experiments to stimulate the formation of fruit by artificial means. In normal conditions the seeds apparently produce growth-promoting substances, the function of which can be carried out by other externally produced chemicals. The most intensive application of this work has been devoted to the tomato, partly because it can be produced under controlled conditions all the year round, partly because it responds readily and partly because the limiting factor to winter production is failure to set, probably due to sterile pollen.

Of the many compounds which have been investigated only one, β-naphthoxy-acetic acid had been developed for practical use. Many amateur gardeners used variants of this substance for the first time this year to obtain setting of their tomatoes. Unfertilised ovaries can be stimulated into fruit growth for upwards of three weeks after the full blooming period if sprayed with this substance. The period for fruit development after artificial stimulation is the same as for normal fruit—between 56–63 days. The spray stimulates all ovaries into growth, whereas under normal conditions sometimes only one ovary in a truss will develop into a full-sized fruit. Artificially stimulated fruits moreover all grow to about the same size. The very vigorous but sterile 'Jack' plants which fail to set fruits normally can be made to develop fruits by spraying with β-naphthoxy-acetic acid. A plant nine feet high with twelve fully developed flower trusses was sprayed and gave 20 lb. of fruit as against the average normal yield per plant of 8–10 lb.

But if these growth-regulating substances are applied in a high concentration to the growing region of the tomato plant undesirable effects follow. Beaked fruits are formed, the stem becomes thin and spindly—in fact it is almost impossible to distinguish these effects from those associated with tobacco leaf mosaic virus.

Strawberries and blackberries which are partially self-sterile have also been sprayed with β-naphthoxy-acetic acid. Berry size has been increased and the yield went up by 50–90%.

Similar favourable reports have been obtained for hops.

Search is now going on for substances which will induce the development of seedless fruits in the tomato but which can be applied to the plant as a whole and which need not, as with present growth regulators, have to be applied to the fruit alone.

Less progress has been made with the artificial setting of apples and pears. But lines of research have been indicated by experiments following a severe frost on May 1 last year when fruit had set and begun active development. The frost blackened the centres of the fruits and killed all the seeds of both apples and pears. On May 5 a combined wash containing several growth-regulating substances was sprayed on the trees. Every fruit on one of the treated trees continued development, but all fruits fell from the untreated trees within fourteen days of the frost.

Another way of avoiding frost damage which is being investigated is by retardation of bud development by means of high concentrations of growth-regulating substances. α-Naphthyl-acetic acid, which is an accelerator at one concentration, inhibits growth at another. Work to prevent or delay bud break resolved itself into a search for inhibitors as distinct from accelerators. The most important substance found is iodo-acetate which inhibits or retards respiration by forming loose molecular compounds with some of the substances involved in cell oxidation-reduction processes. This in turn interferes with the oxygen supply of the cell and slows down metabolic activity. Adrenalin which inhibits root growth in plants acts in a similar way.

Sprouting of potatoes has been delayed by use of growth-regulating substances. In early spring, before warm weather has set in, clamps have been opened and the potatoes treated with a dust containing 1% α-naphthyl-acetic acid in mineral talc at the rate of two to four ounces to each hundred weight of potatoes. This treatment prevented sprout development for three to four months, and the potatoes kept in good condition until the new crop was available.

Hormone Weed-killers

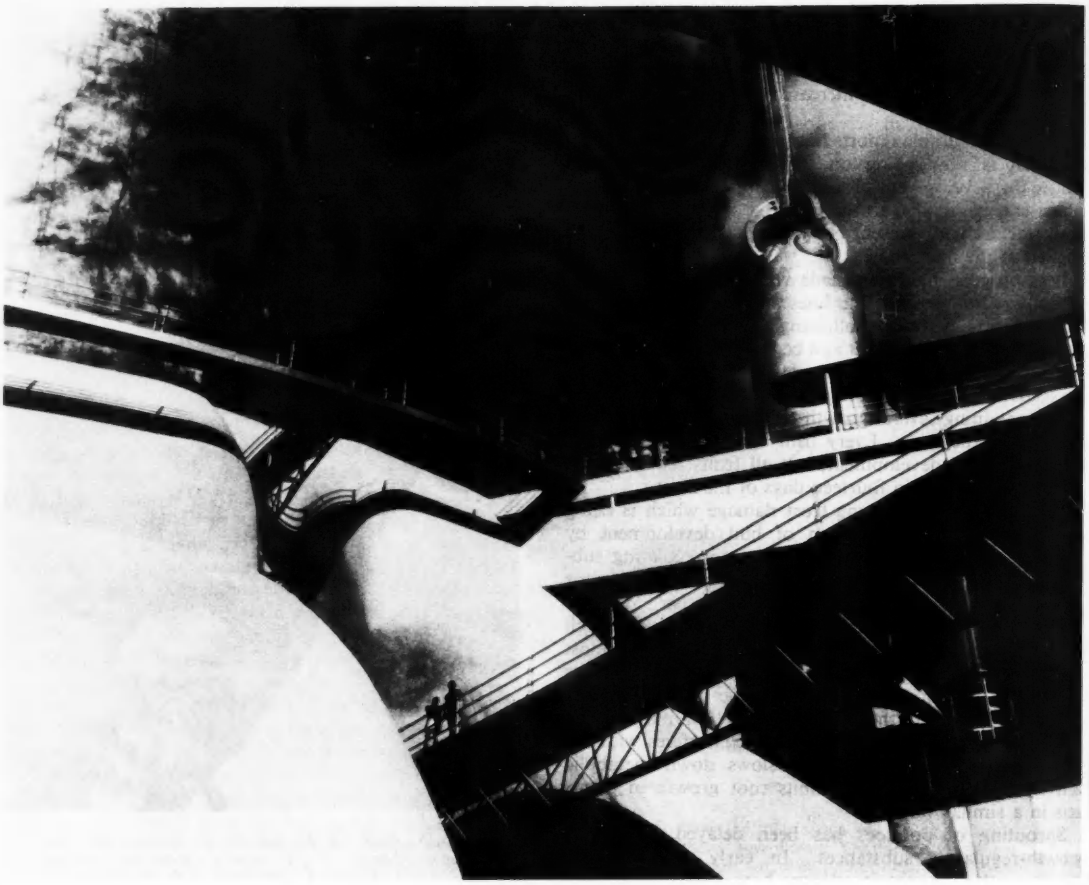
Growth-regulating substances are highly specific, and advantage has been taken of this to use them as weed-killers. One substance 2 : 4-dichloro-phenoxy-acetic acid (DCPA, also known as 2 : 4 D, for short) stops the growing-point elongating, but radial growth becomes excessive so that the stem literally bursts, exposing the inner tissues to direct attack by parasitic fungi and insects. Other substances such as 2 : 3 : 5-tri-iodo-benzoic acid offer promise of being even more effective than 2 : 4-dichloro-phenoxy-acetic acid. 2-methyl-4-chloro-phenoxy-acetic acid (MCPA, methoxone) has already proved a useful selective weed-killer, destroying yellow and white charlock yet leaving cereals such as wheat and oats undisturbed when sprayed or dusted at a rate as low as eight ounces an acre. (A note about methoxone appeared in *Discovery* in November 1945, pp. 327–330; the most up-to-date account of British trials of methoxone is provided in the April 1946 issue of *Agriculture* in which appeared an article on the subject by Professor G. E. Blackman and one on weed control in Norfolk using methoxone by Dr. H. G. Hudson.)

FIG. 5.—Showing the full set of Miller's Seedling apples achieved by spraying with a growth-promoting substance, though all other apples were killed by frost.

Although the science of growth-regulating substances is still only in its infancy, it appears that certain age-old horticultural practices depend on the unwitting use of such substances. For instance, the beneficial effect of farmyard manure and urine in particular, and the time-honoured practice of sticking cuttings in the dung heap during the winter to secure better rooting and the incorporation of cow manure into the old-fashioned grafting clays.

Although many avenues have still to be explored farmers and horticulturists are gaining practical insight into the help that growth-regulating substances can give them, and their own experiments can help the scientists to improve technique if they will report their results.

(The illustrations to this article are taken from the book mentioned on p. 332 by courtesy of Grower Publications Ltd.)



Can Prediction become a Science?

S. LILLEY, Ph.D.

I SUPPOSE the most prominent psychological feature of the world of 1946 is the very prevalent feeling of uncertainty about the future. Not that uncertainty about the future is a new feature in human life—far from it. But the uncertainties of today are in some ways of a quite new type. For the last 250 generations or so, a man could never be sure if his country was going to be involved in a war; but today he has the added uncertainty that he can hardly visualise what that war will be like—atomic, bacteriological or what? For 250 years or so, the average working-man could not be sure that he would have a job next year; but today he has also serious doubts as to whether the particular job in which he is skilled will exist at all in ten years' time.

Doubts and uncertainties of this type are a quite new feature of social evolution. Before about 1700 they hardly existed, and only in the last fifty years at the most have they become really pressing. And the reason is not far to seek. It lies in the increasing speed of technological advance.

Until the great industrial changes of the eighteenth century, technological progress was so comparatively slow that human thought and human institutions could be left to adapt themselves without conscious effort. They lagged a little behind the ideal form required to fit the advancing technology, but the lag was seldom enough to lead to serious dislocation. It was possible to wait till an invention had become successful or a technique had spread through a large part of an industry, and then begin to look for *ad hoc* methods of adapting the social or industrial structure or the psychological outlook of the people concerned to the new requirements. Only once in a few centuries did such passive tactics lead to any serious crisis.

Today the situation is very different. If we wait for an invention to be made, or a technique to become generally economic, then, far too often for comfort, it will prove to be too late to make any smooth adjustments of either institutions or modes of thought. I am far from believing that the atomic bomb is the major cause of present

international tension. But in so far as it is a contributory cause, the reason is that the world left consideration of the problem of how to reorganise itself against the threat of atomic destruction till *after* the atomic bomb became a fact. What a difference it would have made in 1946, and even in 1939, if some twenty years ago men had begun to work out the problems of organising a world in which such technological mass-destruction weapons had been developed—always assuming what it is the purpose of this article to consider: the possibility of such discussion in advance.

That is one of the major problems before mankind at present: to predict inventions and technological developments *before* the fact—or to live in perpetual misery of uncertainty. Can we learn to predict technological changes, and the problems they will create, with sufficient accuracy to permit us to adjust in anticipation our social forms and mental outlooks? It is at least arguable that when social evolution presents mankind with a wholly new problem of this sort, the very same changes that produce it also provide the means for its solution—assuming that men are willing to recognise and develop those means. And indeed, *a priori* there is every reason to believe that a science concerned with the prediction of the technological future is now a possibility. For after all, the studies of economic and technological historians have demonstrated that the technological developments of the past have almost always had well-defined causes which were observable to the seeing eye many years before the development actually took place.

There are causes of a technical nature; in the growth of fundamental scientific knowledge, the appearance of suitably accurate machine tools or appropriate materials, the advances of auxiliary techniques, and so on. In the past the necessity for so many correlated advances before an invention could become generally practicable has led to a time lag, often of the order of fifty years, between the first efforts of a lone inventor and the successful social application. That time lag gives one possible method of prediction—by considering undeveloped inventions and answering such questions as "Are materials of the strength and lightness that this idea obviously requires likely to be developed or not?" But that particular method of prediction is likely to be much less useful in a world in which revolutionary inventions like radar or the atomic bomb can be developed into established techniques in something like five years. So far as technical causes are concerned, the prophet is likely to be driven back a further stage to the thorough examination of the results of fundamental research, to see which of them point to the production of inventions likely to be encouraged by the second group of causes.

Social Needs and Demands

That second group of causes, is of course, the social group. Inventions do not mature into socially used techniques unless there is a need for them within the social framework of the times. More than that, they do not mature unless there is an effective social demand for them. And an effective social demand is often very different from a real need. There is no need for an atomic bomb, but the arrangement (or derangement) of human institutions in the present-day world is such that there is a very high degree of effective social demand for it. Similarly the great need for revolutionary inventions (perhaps of the moving-platform type now well-established among predictors) to solve London's internal transport problem remains unsatisfied, because in present circumstances there is no way in which the need can be transformed into an effective social demand. And lastly an invention matures only if the power behind this effective social demand is great enough to overcome the power behind conservative influences, such as the desire to protect capital from obsolescence when a better potential technique appears.

Attempts at Prediction

A priori, then, it seems quite reasonable to suggest that a scientific examination of the interplay of these various forces—scientific and technical possibility, effective social demand and resistances from vested interests and other sources—would lead to a body of theory on the basis of which future technological developments could be predicted with the necessary accuracy. There have, of course, been many attempts at such prediction. Gilfillan, in an article in *Technological Trends* (1937)*, has made an analysis of the degree of success attained in some of them. Table I shows a statistical analysis of three typical cases.

Judging by the avoidance of blunders, that record is a very good one. On the other hand the proportion of definite positive successes is not very high—certainly not high enough to be very useful in making social and political decisions. The figures in the last column, obtained by adding the probables and half the doubtfuls to the definite successes, look encouraging at first glance. But this first glance is deceptive. The figures represent the proportion of probable successes at some unspecified time in the future. If technological prediction is to be a useful tool in social construction, the predictions must have dates attached. So far few have dared to predict with that precision and their success has not been high.

But it has to be remembered that these, and the countless other essays in prediction, are merely the sporadic, unco-ordinated attempts of more or less isolated individuals. There has been as yet no important attempt to undertake in detail the fundamental analysis that would be required to found a science of prediction. The various attempts, though often made by men expert in the scientific method, have not yet been carried out on an essentially scientific basis. The best that can be said is that they are the products of acute intuition, modified by a rational, but far from systematic, survey of the available evidence. Again, there has been nothing in the nature of a 'school of prediction'—no bringing together of suitably balanced team of scientists, technologists, historians and sociologists to give those several years of work that are essential to the foundation of any science. Nor has there been any notable development of that other and looser form of co-operation that is frequently so fruitful, in which several workers in a field publish results, criticise and comment on the work of others, and by their mutual interaction

* *Technological Trends and National Policy, including the Social Implications of New Inventions.* (1937, U.S. Government Printing Office, Washington.)

Date of prediction	*Proved right by* 1937 (*A*)	*Probably destined to be right* (*B*)	*Proved wrong by* 1937 (*C*)	*Probably destined to be wrong* (*D*)	*Still doubtful in* 1937 (*E*)	*Estimated eventual success* ($=A+B+\frac{1}{2}E$)
	%	%	%	%	%	%
1906	46	24	21	—	9	74
1915	28	48	—	—	24	88
1920	38	29	8	3	22	78

TABLE I

advance the science they are interested in. The results of Table I have been obtained by isolated individuals, using a method which is no more than rationally controlled intuition. The question is: could the teamwork of many, devoted to a really scientific analysis of the causation involved in technological progress, give the sort of result that is required? Could it make possible predictions of 95 or even 99% accuracy, on which it would be possible to take social action?

H. G. Wells was one of those who maintained that it could. He made an inspiring appeal for a science of prediction in a Friday evening lecture to the Royal Institution in 1902. That paper was regarded so highly at the time that not only was it published in *Nature* and the *Proceedings of the Royal Institution*, but it was also selected for printing in the *Annual Report of the Smithsonian Institution* as one of the important general papers on scientific matters for the year. "I must confess," said Wells, "that I believe quite firmly that an inductive knowledge of a great number of things in the future is becoming a human possibility. So far nothing has been attempted, so far no first-class mind has ever focused itself upon these issues. But suppose the laws of social and political development, for example, were given as many brains, were given as much attention, criticism and discussion as we have given to the laws of chemical composition during the last fifty years—what might we not expect?"

Wells himself made many predictions, with about average success. His greatest contribution, in fact, lies not in his own predictions, but in his faith that a science of prediction was possible and in his appeals to have it made an actuality. It will be in keeping, therefore, with his spirit, if we use his own works to illustrate some of the problems that a science of prediction must face. I am not concerned here with his futuristic novels—though is it worth noting that in one of these, *The World Set Free* (1914), he predicted the atomic bomb, and did so on the basis of the scientific material contained in Soddy's *Interpretation of Radium*; rather I am concerned with his more sober attempts to forecast the future, such as *Anticipations* (1902). The first chapter of that book is largely devoted to the effects that motor cars, buses and lorries would have on the structure of society. It contains its blunders, and certainly his suggested future of the railways is wrong; yet in the main the prediction is excellent. This exemplifies one of the major lessons that can be drawn from many prophetic essays—that a very high standard can be attained, even with present imperfect methods, in predicting the effects that will arise when an invention, already technically achieved but only in limited practical use, develops into a widespread technique. On the other hand, Wells fails abysmally with another invention in transport that was just around the corner in 1902—the aeroplane. That it is practicable, he agrees; but he continues: "I do not think it at all probable that aeronautics will ever come into play as a serious modification of transport and communication . . ." his chief argument being man's "considerable disposition towards being made sick and giddy by unusual motions, and however he soars he must come to earth to live."

His predictions about war are particularly interesting. His forecasts of individual technical weapons are almost all wrong. His flying machines are based on balloons having contractile gas containers, which can be used in the same way as a fish's swimming bladder to raise or lower the ship. These will be ranged in lines fore and aft of the aircraft, and by contracting them at one end and expanding them at the other the ship will be tilted. A suitable disposition of planes will then produce from this tilt a swooping motion; and that will be the chief mode of progress. His airships will not be able to carry much armament; ramming will be their chief weapon, and in terms of ramming instead of machine-gun fire, he visualises something very like the battles of fighters that we are now accustomed to. He thinks the submarine will not be an effective weapon. He foresees tanks, but does not think them of high value; he conceives them to be very slow and unwieldy. He puts tremendous emphasis on highly manœuvrable bicycle troops.

Yet out of all this he obtained in 1902 a picture of future war that describes 1939-45 much better than 1914-18. The point is that, though his forecasts of weapons fail from attempts to describe them too minutely, nevertheless the general nature of those weapons is correct. His aircraft are technically absurd, but suppose he had merely said, "There will be aircraft," as anybody in 1902 was justified in saying. That would have been sufficient. Given the aircraft, he accurately predicts aerial warfare, high-explosive and incendiary bombing, co-operation between land and air forces, and the tremendous advantages that will accrue to the side that obtains mastery of the air. Though his tanks are inadequate and his cycle troops never in fact achieved decisive importance, those two concepts, along with some others, enabled him to predict the highly mobile nature of modern war. His general picture of the increasing use of technical weapons allowed him to foresee something of total warfare, and even to catch a glimpse of the role of scientists, technicians, engineers and agriculturists in the war that was then thirty-seven years ahead.

All this points to one elementary lesson about the methods of technological prediction. We may predict almost every individual invention wrongly; yet if we are genuinely following out the general technological trends of the time, and if we do so over a sufficiently wide field, the result may be an excellent prediction of the total effect. That this is no accident is shown by the fact that the prediction could have been done just as well without reference to particular inventions at all. Wells would have reached his forecast of the general nature of war, if his argument

had been something like this: "Technological trends of the present will clearly soon provide means of flight. They will greatly increase speed of manœuvre on land. They will provide transport that will enable armies to be greatly increased in size. They will put more emphasis on the productive forces behind the fighting line. . . . Therefore the general nature of a future war will be . . ." (and I suspect that in his own mind the argument did run on those lines, the detailed inventions being an afterthought designed to tickle the palates of certain types of readers).

General versus Specific Predictions

The moral for forecasters is: Do not predict individual inventions in detail—that is usually a waste of time. Concentrate on two things; first, the extrapolation of present trends (for example, the further development of already existing petrol-driven land transport in the case under consideration); second, predictions of the form "it will become possible to fly." In 1902 there were several possible ways in which flight might at any moment be achieved. The chance of success for any one of them might be small; but the probability of *at least one* succeeding was very high.

Later in the same book Wells provides another excellent illustration of this point. In 1902 it would have been folly to predict which (if either) of Britain or U.S.A. would take the lead in flight or television or straight line mass-production, or any one particular line of development. Wells chose a much better method, when he wrote: "The United States of America are rapidly taking, or have already taken, the ascendancy in the iron and steel and electrical industries out of the hands of the British; they are developing a far ampler and more thorough system of higher scientific education than the British, and the spirit of efficiency percolating from their more efficient businesses is probably higher in their public services. These things render the transfer of the present mercantile and naval ascendancy of Great Britain to the United States during the next two or three decades a very probable thing." Note that here we have a correct prediction *with date attached.* Britain today might be in a less unpleasant situation if that prediction had been heeded (which brings me to remark parenthetically that one of the great advantages to be derived from prediction is that, within certain limits, we can use the results of prediction to falsify those of its features which may be undesirable).

Gilfillan, in the article already referred to, discusses a very similar aspect of prediction—what he calls the *principle of equivalent invention.* The predictor need not be concerned with how a technical problem is to be solved, but only with whether it will be solved or not. He instances the problem of flying in fog (he was writing in 1937) and points out that there were about twenty-five likely means of solving it. These included fog dispersal, several radio suggestions which virtually cover radar, and to pick two instances which, so far as I know have not been developed, trailing a television transmitter below the clouds and the use of infra-red light to view the ground. Of the twenty-five possible methods, not all were likely to be blind alleys or eccentric products of brainstorms, or even unpracticable for unforeseen technical reasons. Hence it was possible to conclude almost with certainty that the problem would soon be solved. I suppose that we can now say that it has largely been solved, and I note that about ten of the suggested methods which Gilfillan lists are now in use. The point is that we are not concerned with the prediction of inventions, only with their effects. And the fact that there are almost always many possible inventions that could lead to the same desired effect enormously increases the chance of successful prediction. The more widely varied the methods are, the less chance of some common unseen factor rendering them useless in practice, and so the greater chance of accurate prediction.

I said earlier that there has as yet been no important attempt to use the joint efforts of many experts for prediction. There is, in fact, one partial exception to that remark—the work embodied in *Technological Trends* (1937), the U.S. Government report in which Gilfillan's article appeared. This was one of the results of the New Deal attempts to overcome the effects of the economic crisis of the 1930's. It was intended to help New Deal planning by predicting the trends of technology for the next few years and discovering what their social effects would be.

I have to confess that it was no more than moderately successful. Many of the discussions of quantitative trends with established techniques (as opposed to qualitative leaps to new techniques) were quite near the mark. On the other hand, there was surprising failure to predict, or even to notice the possibility of, some of the more radical inventions which were just around the corner. The section on air transport, for example, makes no mention of jet propulsion or of helicopters, although both were then under active experimentation and current results were good enough to require at least very careful consideration.

The remarks on the use of radio for safety could not be stretched to cover the implications of radar (but note how Gilfillan in another article took radar in his stride). In almost every respect the article on flight is too conservative—"Technical developments of the planes themselves are slowing down" is a phrase only too typical of the general tone. In the same way, the article on power fails to mention atomic energy, even in a section that briefly discusses such possibilities as tidal power, wind power, power from thunderstorms (*sic*), direct use of solar energy and photo-chemical possibilities. If thunderstorms were worth mentioning (only to dismiss them, of course), then surely the then familiar knowledge of nuclear energy would have made it worth while at least to consider whether methods of releasing and controlling it were feasible. The gas turbine is also omitted from the list of prime movers, though it was by that date in limited use and showing much promise.

Technological Trends would at first sight seem to lessen our hopes that a science of prediction is possible. But I believe that fuller consideration of this report will show good reasons why it was not more successful. To begin with it was only superficially a product of teamwork. There was some committee work, but in most cases the articles appear to have been written by separate experts working individually. Again, there is little sign in it of any attempt to establish general laws of causation and then apply them to prediction. The earlier articles do consider causation

in a general, but not very deep, sort of way. But the predictions in particular fields seem to have been made independently of that general analysis, and to have used no more subtle methods than what I have called 'rationally controlled intuition'.

The Results of Bias

What is, perhaps, more important is that the opinions expressed in *Technological Trends* are only too clearly influenced by the circumstances in which the book was written. The 1930's was a period of slowing down in technological advance—at least in radical technological advance, though the rate of minor improvement was still going up. Major technological changes were less frequent than in, say, the period 1880-1910. The slowing down was due to a reduction in incentive, arising in turn from the world economic depression and (as we now know as a result of war-time revelations) from the conservative influence of monopolies seeking to protect capital and the machinations of international cartels. A few decades earlier, whenever science uncovered a new possibility, there was a rush to exploit it in practical form; in the 1930's it was more often left alone, at least by corporations in command of adequate resources. *Technological Trends* was clearly written on the assumption that this situation would continue—which we now know to have been a false assumption. Now it might be suggested that the authors of that work could have seen the causes of the current retardation, deduced that it was abnormal, and corrected their predictions accordingly; at least, that they could have stated an alternative set of predictions allowing for a revival of the rate of progress. But that would have implied at least a measure of criticism of the existing social structure of the U.S.A. With a very few notable exceptions, the authors of *Technological Trends* were not the type of men to take such a course. Indeed it was unlikely that an established government would pick men who would produce a critical report. Though liberal and progressive in form and method, the New Deal policy was, after all, essentially conservative. Its business was to solve the most pressing economic problems facing the United States without making or suggesting fundamental social or economic changes.

That conception is reflected in *Technological Trends*. To take but one example, the problem of technological unemployment receives a large proportion of the space. One gets the impression that it is regarded by most of the authors, not as an evil of social organisation, but as a more or less inevitable result of technical advance. To think otherwise would be to make those unwanted criticisms—but to accept it as inevitable is to hope (though perhaps not very consciously) that there will not be too much of that advance, and so to risk biassing one's predictions.

Of course, the main reason why *Technological Trends* failed in its predictions was that it failed to foresee that the depression of the 'thirties would be transformed into the war of the early 'forties, and that the war would greatly decrease the influence of the retarding forces. Again one might expect the ideal predictor to have recognised the signs that war within a few years was highly probable, and to have varied his predictions accordingly or given alternatives. But again the same factor comes in: to have done so would have been to criticise the existing régime.

These reasons for the failure of *Technological Trends* (if I am right in my analysis) point to one of the greatest difficulties to be faced if a real science of prediction is to be created. Some means must be found of freeing the investigators from those influences, both internal and external, which prevent them from making fearless criticisms of that which exists and so tend to bias their estimates. The condition is easily stated; the method of achieving it much more difficult.

I have ranged the evidence strongly against the possibility of prediction being successful enough to be useful. And I have then tried to explain it away—with what success, it is for the reader to judge. Yet I must confess that I remain on the side of H. G. Wells. I believe that successful prediction is possible. If I am right, then the examples of the past, from Wells himself to *Technological Trends*, will in their various ways help to show the conditions on which successful prediction depends. It depends on more scientific methods of causal analysis than have hitherto been used, and on a concentration of far more serious attention on the subject. It depends on finding means of freeing the investigators from the effects of undue social conservatism. It depends on finding solutions to a great many other problems, of which I shall mention only one more.

Gilfillan claims that, with notable exceptions like Wells's *Anticipations*, attempts at prediction of military matters have been singularly unsuccessful. And he gives as one of the reasons that "the latest developments and projects are held so closely secret, that it is impossible for an outside author to outguess the silent experts." At a time like the present, when military secrecy is tending to spread into many fields of science and invention and to restrict free publication of matter that is very far from being directly military, those difficulties might well make prediction impossible in any technological field. The moral does not need emphasising.

In conclusion, let me stress again that I am not here concerned with these technological-sociological investigations and the hoped-for science of prediction as academic exercises—though that would not prevent some whose outlook was mainly academic from giving great help. I am concerned with it as a way of improving the conditions of life, specifically as an aid to planning the course of social evolution in such a way as to avoid those now too familiar conflicts between technological instruments on the one hand and human thought and social institutions on the other. I am thinking of it as one element in the process, which has been becoming more important in the last few decades, by which mankind is coming more and more to control its own social evolution, instead of leaving it to the interplay of blind and uncomprehended social and economic forces.

Technological prediction should be an important element in helping to plan the future, to control the future of human society. At the same time the fact of that planning should help to make the prediction easier.

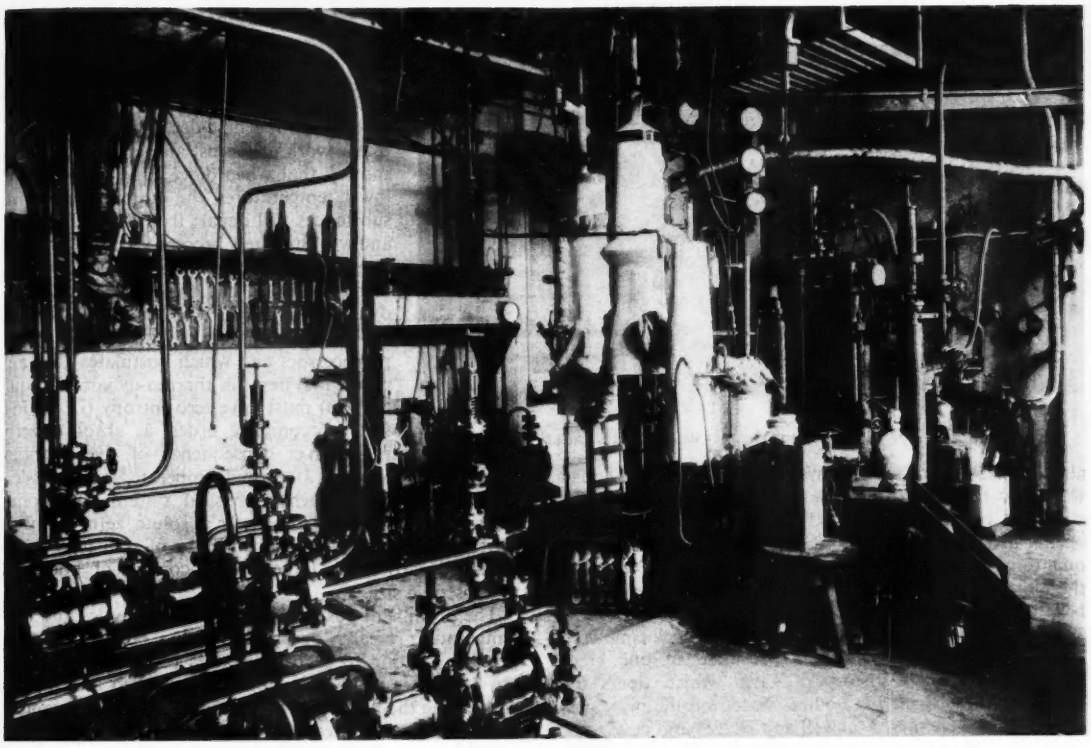


FIG. 1.—An early air-liquefaction plant working with the 'cascade' method (*Leyden*).

Low-temperature Physics

K. MENDELSSOHN, M.A., Ph.D., F.Inst.P.

THE first international conference of physicists after the war was held this July at Cambridge under the auspices of the Physical Society. The two subjects under discussion were 'Fundamental Particles' and 'Low Temperatures'. In view of the outstanding advances made by nuclear physics in the decade preceding the war and particularly in view of the large scale release of atomic energy, general interest in the properties of nuclear particles is obvious. It may be understood less readily, however, why the physics of low temperatures was chosen as the second subject.

The reason is to be found in the ever increasing importance of quantum physics. By the end of the last century the description of the phenomena of our physical world by means of the concepts and laws of classical physics was almost complete. Knotty problems in such fields as hydro- and aero-dynamics admittedly remained to be treated more rigorously but on most of the frontiers of physics the usefulness of the classical methods appeared to be exhausted. On the other hand there remained problems of the utmost importance, as for instance the generation of light and conduction of electricity, which had defeated all attempts at solving them, and it became increasingly clear that what was needed was not a further elaboration of the accepted system but an entirely new principle of physics. When in 1901 this new principle made its appearance in Planck's radiation formula, it passed almost unnoticed. The great significance of the quantum principle and its general importance was first recognised eleven years later when Einstein, Nernst, Lindemann (now Lord Cherwell) and others showed that it offered a means of explaining the decrease of specific heats (the specific heat of a substance is a measure of the amount of heat needed to warm unit mass of the substance by 1°) which had been observed in all substances when their temperature is lowered.

The laws of classical physics generally deal with samples of matter which consist of large multitudes of individual particles. Classical mechanics were developed not upon observations of the motion of single atoms or molecules but through experience with bodies composed of millions upon millions of separate units. The failure of the physicists of the nineteenth century to develop a microscopic theory of the properties of matter was due to the fact that they always made the tacit assumption that classical laws were

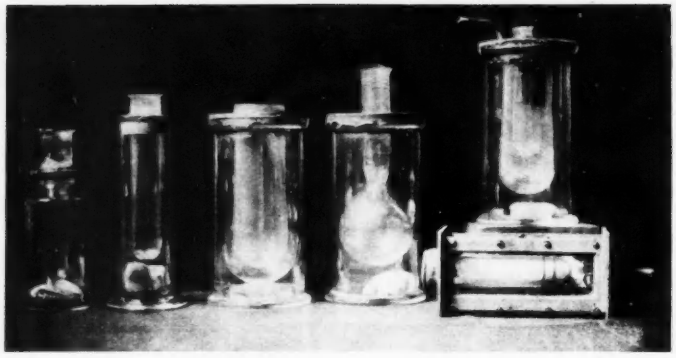


FIG. 2.—Forerunners of the vacuum flask (*Royal Institution*).

also applicable to the mechanics of single atoms. Today we know that the forces which are responsible for the structure of solid matter—the forces of cohesion, of chemical binding and the forces in the nucleus—are quantum mechanical forces which have no counterpart in the world of classical mechanics. They could never have been derived from the principles of the old physics.

Nevertheless, application of classical principles to individual atoms and molecules resulted in one great advance, the kinetic theory of gases, which treats the particles as freely moving bodies. Based on the principles of classical mechanics, Maxwell and Boltzmann developed the statistical picture of an 'ideal' gas which substituted a microscopic model for the parameters of thermodynamics such as temperature and pressure.

The success of the kinetic theory in accounting for the laws of Boyle and Charles, as well as for the observations on heat conduction, viscosity and diffusion, seemed to provide full justification for the application of classical physics to single atoms. The specific heat of gases, too, followed directly from the theory, and by introducing potential as well as kinetic degrees of freedom, an explanation could be given for the empirical law of Dulong and Petit. This rule, which was found as early as 1819, states that the specific heat (more correctly the atomic heat), of a solid element is 6·3 calories per gram-atom* irrespective of the atomic weight or the crystal structure. While this law holds for most substances and while higher values of the specific heat can be easily explained, there exist a few elements which have much lower specific heats. The most notable of these is carbon in the form of the diamond with an atomic heat of only 1·4, a figure far removed from 6·3. Weber showed in 1875 that even these elements when heated well above room temperature will attain the value of the specific heat demanded by the law of Dulong and Petit.

The significance of these anomalies was revealed in the first decade of this century by the work of Nernst and his school. They showed that when descending to lower and lower temperatures, the atomic heats of *all* substances will depart from the value of 6·3 and will ultimately become vanishingly small. These observations were coupled with the formulation of the third law of thermodynamics in 1908. This theorem, which in fundamental importance fully equals its two predecessors and which postulates that any physical system (in thermo-dynamical equilibrium) must have zero entropy (i.e. be in a state of complete order) at absolute zero, is a direct consequence of the quantum principle. But whereas at normal temperatures the classical laws become invalid when physical systems of atomic dimensions are considered, near absolute zero quantum physics also determines the behaviour of statistical multitudes of particles and the energy content of bodies of macroscopic size.

The prominent position which nuclear physics and low-temperature research occupy in modern physics and their peculiar relation to each other thus become clear. They are both lines of investigation which lead to information concerning the behaviour of structures subject to quantum laws. These structures are very different in the two cases. Nuclear research deals with single particles or with small agglomerations of them, while the specimens used by the low-temperature physicist are samples of matter of ordinary dimensions. Nevertheless, there begin to be apparent peculiar and completely unsuspected similarities. The system according to which energy is distributed among the particles forming an atomic nucleus seems to bear a certain resemblance to the energy spectrum of a volume of liquid helium near absolute zero. So far we are largely ignorant of the true meaning of many observations in both

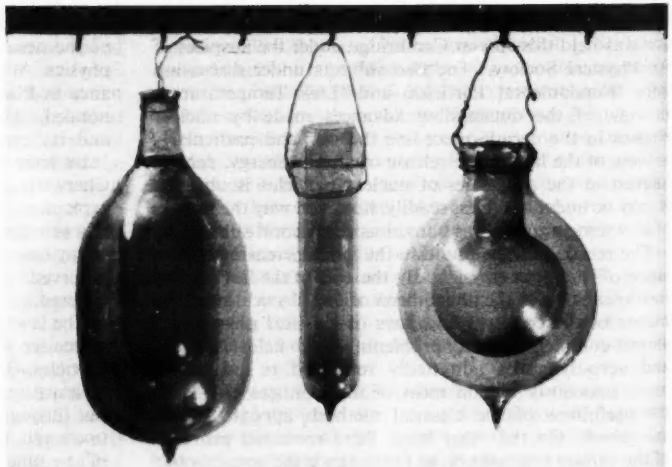


FIG. 3.—Dewar's first vacuum vessels.

* Gram-atom is the quantity of an element whose mass in grams is equal to its atomic weight. Dulong and Petit based their rule on the observation that for many substances (more particularly the metals) the specific heat was inversely proportional to the atomic weight; in other words (specific heat × atomic weight) was constant, approximately equal to 6·3.

fields, and this is the surest sign that the progress of low-temperature research like the advance of nuclear physics is penetrating into the unknown territory of our physical world.

There is another resemblance between nuclear physics and low-temperature research which, while quite superficial, is nevertheless very important. Like that of modern atomic research, the technique of low-temperature investigation is intricate and fairly costly. Gas liquefaction, an indispensable adjunct, requires compressors, pumps, liquefiers and Dewar flasks. While it is possible to produce occasionally small amounts of liquid helium in the framework of a physics department of average size, a full-scale low-temperature plant with liquefaction of air, hydrogen and helium and with a magnetic cooling installation requires as much capital outlay and servicing expenses as a fair-sized cyclotron. The men to run it are, of course, at least as important as the machines. A complicated experimental technique cannot be learned from text-books or scientific publications; its mastery depends on knowing a thousand little tricks which are acquired in the laboratory and handed down from one generation of research workers to the next. The inevitable result is the development of strong 'schools' and in the field of low-temperature research one such school, that of Leyden, has acquired almost legendary fame. In order to appreciate this development of technique and the difficulties which had to be overcome, we must go back almost 70 years.

A Milestone

It is not often that the birthday of a new branch of science can be fixed with any degree of certainty; however, that of low-temperature physics is without doubt the Christmas Eve of 1877. On that day there was read before the French Academy of Sciences a letter sent in by Louis Cailletet (it was dated December 2), which announced the liquefaction of oxygen. The members of the Academy had scarcely begun to contemplate the importance of this communication when the secretary announced that on December 22 he had received a telegram from Raoult Pictet also reporting the liquefaction of oxygen. As so often in the history of science, and testifying to its organic development, the same advance which was due to come had been made simultaneously and independently by two workers. Cailletet worked at Châtillon sur Seine while Pictet had carried out his experiments at Geneva, and they had reached the same goal by entirely different methods.

The achievement of Cailletet and Pictet is a milestone in the researches on gas liquefaction which had then been going on for nearly a century. In 1782 van Marum had tested Boyle's law on ammonia and had found that at high pressures the product of volume and pressure began to deviate more and more from the theoretical value, until finally the gas condensed. From then onwards a great many attempts were made to force all the known gases into the liquid state.

The most spectacular of these experiments were perhaps those of Aimé who in 1843 subjected a number of gases to high pressure by sinking them in suitably designed cylinders to a depth of 7000 feet into the ocean. However, while these and similar efforts proved successful with a number of gases, other gases, in particular oxygen, nitrogen

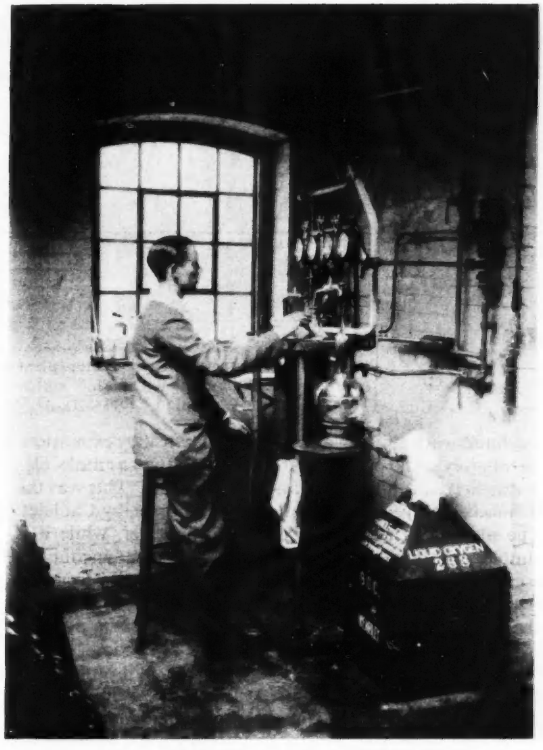


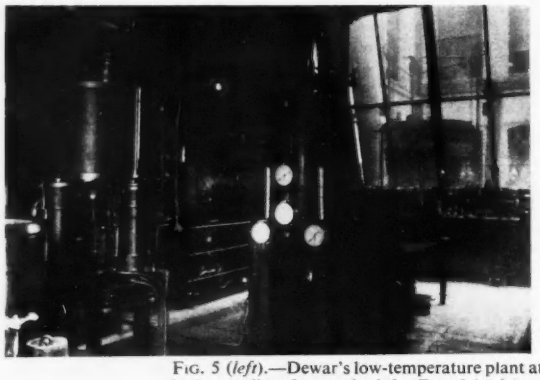
FIG. 4.—A medium-size hydrogen liquefier in operation; the liquid is siphoned into the spherical vacuum vessel.

and hydrogen, showed no sign of liquefaction even under pressures as high as several thousand atmospheres. Nevertheless, scientists were convinced that these 'permanent gases', too, could be turned into liquids. It soon became apparent that cooling facilitated the process of condensation, and as early as 1822 Cagniard de la Tour showed that above a certain temperature ether does not exist in the liquid state even under the highest pressures. The full significance of the existence of a *critical point* was not realised until forty years later but Faraday seems to have sensed the importance of this work since in his papers he referred frequently to the 'Cagniard de la Tour point'.

The whole question of the transformation of gases into liquids was solved by the fundamental experiments of Andrews in 1863 who systematically measured the isotherms* of carbon dioxide and who demonstrated conclusively that in order to pass into the liquid state a gas must be cooled below its 'critical' temperature. It became clear at once that the permanent gases resisted liquefaction because their critical temperatures were too low to be reached by the available experimental means. From then onwards the story of gas liquefaction became the story of low temperatures. By applying the results of Andrews's work Cailletet and Pictet succeeded in the liquefaction of oxygen.

The simplest way of cooling a gas is by enclosing it into

* A graph of isotherms is obtained by plotting pressure against volume for a gas kept at constant temperature.



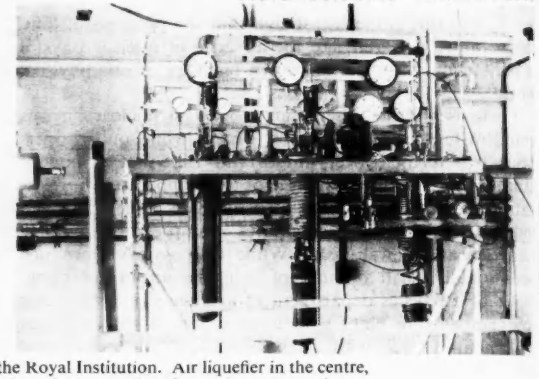


FIG. 5 (*left*).—Dewar's low-temperature plant at the Royal Institution. Air liquefier in the centre, hydrogen liquefier on the left. FIG. 6 (*right*).—A large hydrogen liquefier under construction at the Clarendon Laboratory, Oxford. The coiled tubes are heat-exchangers.

a cylinder with a piston and letting it do work by expansion. In this way some of the kinetic energy of the gas molecules is transferred to the piston and the gas cools. This was the method employed, in a slightly modified form, by Cailletet. The method of adiabatic expansion, however, while it is simple and has a good cooling efficiency, encounters considerable technical difficulties when one tries to adapt it to a periodically working cooling engine. In particular the absence at low temperatures of lubricants for the moving parts of the system is a serious drawback. Pictet, on the other hand made use of the heat of evaporation. His liquefaction plant consisted of three cycles in which he circulated sulphur dioxide, carbon dioxide (or nitric oxide) and oxygen. In each cycle the gas is liquefied under pressure at the lowest temperature obtainable by means of the preceding stage. The liquid is then cooled by drawing off the vapour with a suction pump, and the compressed gas of the next cycle is cooled to the lowest temperature thereby obtained. Such a series of cooling cycles is called a 'cascade', and cascades soon became the method of choice for the early experimenters with liquid air. Besides having a fairly high cooling efficiency, the cascade requires no moving parts at low temperatures, the compression and pumping being carried out at room temperature.

While it is true that the French experimenters had liquefied oxygen and thereby obtained a temperature of almost -200 C, the liquid was not in a form which lent itself to investigations at this low temperature. All that they were able to produce was a spray or a mist of oxygen droplets which evaporated as soon as they had been created. The next step was taken by Olszewski and Wroblewski at Cracow who shortly after 1880 began systematically to develop apparatus and procedure for experiments at low temperatures. By introducing liquid ethylene as a cooling agent and by shielding the experimental vessel by concentric layers of cooling agents against heat influx, they succeeded in keeping oxygen in the liquid state long enough to carry out a number of determinations of physical data. They also liquefied carbon monoxide, methane and nitrogen, and by reducing the vapour pressure of the latter (pumping off until the liquid solidified) they reached a temperature of -225°C.

While the cryostats ('cryostat' is a generic term covering apparatus maintaining a constant low temperature) developed in this way at Cracow were a very great improvement on the early experiments, they did not constitute an ideal solution. It was left to the ingenuity and the experimental skill of Sir James Dewar to find the ideal solution of the problem of storing liquefied gases, the vacuum flask. As the accompanying photographs show, Dewar started with a technique rather similar to that of the Polish scientists and depending on the use of concentric glass tubes. He introduced dehydrating materials into the intervening space to prevent condensation of moisture and this arrangement led ultimately to the development of the vacuum flask.

The invention of the Dewar vessel was a necessary prerequisite not only to satisfactory experiments with liquid air but also to the next great step towards absolute zero, the liquefaction of hydrogen. This latter problem presented peculiar difficulties. The work of van der Waals, which had led to his law of corresponding states, permitted the estimation of the critical temperature of hydrogen from deviations from Boyle's law at higher temperatures. These calculations showed that the critical point would lie well below the lowest temperature which could be reached with any of the liquefied gases. The cascade, which at that time was the only feasible method for large-scale liquefaction, relies of course on the existence of overlapping liquefaction cycles. The lack of a suitable cooling agent to bridge the gap between the temperature of solid nitrogen and the critical point of hydrogen barred the progress to lower temperatures until a new cooling method had been found.

In 1895 Hampson and Linde independently filed patent applications for the well-known method which has since become the most important industrial process for liquefying air. Their combination of expansion without external work (the Joule-Thomson effect) and a heat exchanger is inferior in cooling efficiency to adiabatic expansion. However, the method is simple and requires no moving parts at low temperatures. Only three years later Dewar succeeded in liquefying hydrogen with the same method. Modern accounts show a tendency to underrate Dewar's achievements, possibly because he failed to found a flourishing school. However, while Dewar's attitude seems to have favoured the work of the individual rather than that of a large research team, this does not mean that his research was unplanned. On the contrary,

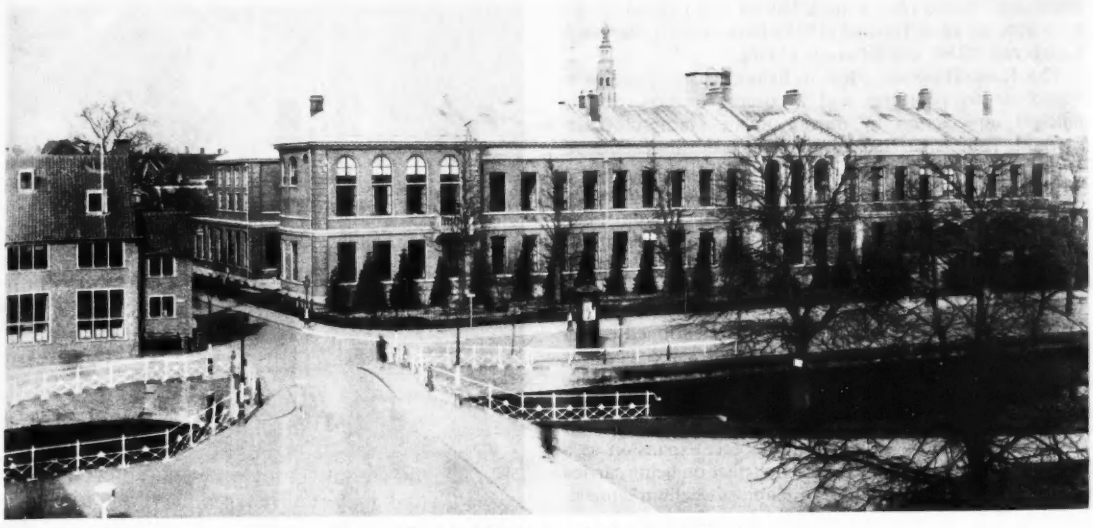


FIG. 7.—The Kamerlingh Onnes Laboratory at Leyden.

the successful solution of a whole series of major problems within a remarkably short time and with limited resources, indicates careful methodical planning coupled with shrewd foresight and unbounded enthusiasm.

Liquid hydrogen has a boiling-point of 20° K. and by rapidly pumping off vapour from the solid phase (triple point* at 14° K.) a temperature of about 11° above absolute zero can be reached. When Dewar began his work, hydrogen was the last of the 'permanent' gases known, and its liquefaction had to be considered as the only remaining step in the approach to absolute zero. However, in 1895 helium was first found in minerals (its existence had been postulated in 1868 from solar observations) and in the same year Olszewski found that the new gas resisted liquefaction even more strongly than hydrogen. Between 1901 and 1904 Dewar and Travers tried unsuccessfully to liquefy helium by cooling it under pressure to the lowest temperature accessible with liquid hydrogen, and Dewar concluded that the critical point of helium must lie in the neighbourhood of 6° K. This estimate, based on scanty data, proved remarkably accurate when helium was liquefied four years later. However, it was not for Dewar to achieve this last crowning success in the story of gas liquefaction.

The theoretical background for the development of gas liquefaction had been created by van der Waals in Holland and it was there that the most remarkable achievements in low-temperature physics were to be made. In 1882 Kamerlingh Onnes was appointed Professor of Physics at Leyden. When he retired almost forty years later, the Leyden Laboratory which now bears his name had become the undisputed centre of low-temperature research. Scientists from all over the world went to work with Onnes at Leyden where he had created research facilities on an unparalleled scale. He had set out to furnish the experimental data supplementing the work of van der Waals and had ended up by providing cryostats for any kind of research at any temperature between the ice point and 1° K. His life-work stands out as a superb effort of planning and organisation which is unique in the history of scientific research. More than half a century ago, Kamerlingh Onnes recognised that the planning of experiments and the design of apparatus is but one part of modern physics. Side by side with the scientific work he built up at his laboratory schools for glass-blowers, instrument makers, and mechanics which in due course were to provide the highly skilled technicians required for his work. He had a passion for accurate determinations and true to his motto *dor meten tot weten* ('through measuring to knowing') he would not embark on an experiment, however tempting, unless it had been prepared to the last detail.

Thus it was not until 1906 that hydrogen was liquefied at Leyden. However, the liquefier constructed by Kamerlingh Onnes could produce quantities large enough to serve as cooling agent for the last stage of gas liquefaction, that of helium. By 1908 Onnes had built a liquefaction plant for helium and had collected 360 litres of the rare gas. Helium was first liquefied on July 10 in that year. A vivid account of this memorable occasion is given in No. 108 of the "Leyden Communications", the scientific journal issued by the laboratory. The "Communications" make epic reading. Extending now over more than half a century they contain in the form of scientific papers the history of low-temperature research from its early beginning to the present day.

While many interesting problems remain to be solved in the temperature regions of liquid air and liquid hydrogen, the main interest of low-temperature physics has now shifted to the region below 10° K. This, as we shall see later, is due to a number of strange and quite unexpected phenomena which have been discovered in this temperature region. There has been an increasing demand, therefore, for research facilities of this kind and, while Leyden still remains the largest low-temperature laboratory in the world, plants for helium liquefaction have been installed

* The temperature at which solid, liquid and gas exist together.

elsewhere. Large plants modelled on the Leyden prototype were set up at Toronto (1923), Berlin (1925), Berkeley, California (1934) and Kharkov (1936).

The Joule-Thomson effect in helium is still positive at liquid air temperatures and in order to carry out an efficient liquefaction by means of the Hampson-Linde method, helium gas has to be pre-cooled almost to the triple point of hydrogen. Unlike liquid air and its constituents, liquid hydrogen cannot be obtained commercially, which means that a helium-liquefaction plant requires for its operation an even larger hydrogen plant. It was therefore a considerable simplification when in 1934 Kapitza working at the Royal Society Mond Laboratory in Cambridge designed a helium liquefier which did not require liquid hydrogen. We have mentioned earlier that for a number of reasons the use of a reciprocating expansion engine for gas liquefaction presents considerable difficulties. Claude and Heylandt finally overcame these objections in the case of air liquefaction by using pentane as lubricant and by employing adiabatic expansion as a pre-cooling stage only, the actual liquefaction being carried out by Joule-Thomson cooling. Kapitza's helium liquefier works according to the same principle. The gas is pre-cooled by means of a reciprocating expansion engine to below the inversion temperature of the Joule-Thomson effect and then liquefied by the Hampson-Linde process. The lubrication difficulty is overcome ingeniously by using helium gas as a cushion between the cylinder walls and a loosely fitting piston. The Kapitza liquefier in Cambridge is giving excellent service and has been followed by machines of similar type at Yale and Munich and at Kapitza's new, large, low-temperature laboratory in Moscow.

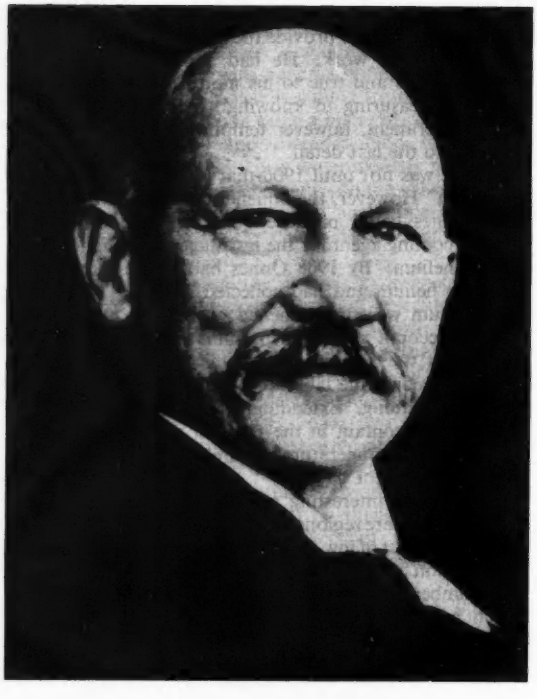


FIG. 8.—H. Kamerlingh Onnes.

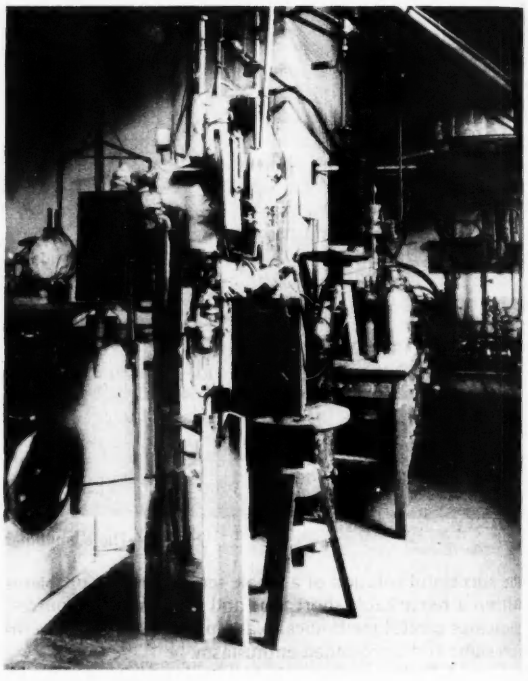


FIG. 9.—Onnes's original helium liquefier.

Whatever method is employed, a plant delivering at its final output several litres of liquid helium demands compressors, pumps and gas holders of considerable dimensions and proportional cost as well as a large supply of helium gas. The whole purpose of this is to cool to temperatures below 10° K. specimens of usually very moderate size. Moreover, according to the quantum theory the heat capacity of these specimens is in most cases negligible compared to that at room temperature. This means that for the majority of experiments a few cubic centimetres of liquid helium is all that is really required. It was with ideas like these in mind that in 1926 Simon, one of Nernst's former pupils, began to develop a technique of experimentation which was especially adapted to the peculiar conditions of the liquid helium region. Since then he and members of his school have designed a great number of helium liquifiers on the lines of what has become known as the 'small-scale cryogenic technique'. The essential feature of this method is that for each type of experiment a specially adapted helium liquefier is constructed which will provide a small quantum of liquid helium. The liquid is kept in the liquefier where the experiment is then carried out. Since the total cooling capacity is small, special care has to be taken to guard the cold parts of the apparatus against influx of heat. In comparison with an ordinary helium liquefier, the liquefaction unit of a small-scale cryostat is very simple. It may work by one of three different cooling methods: desorption, Hampson-Linde or adiabatic expansion.

Desorption Method

Simon's desorption method is a return to the old cascade system which had to be abandoned below liquid air temperatures because of the lack of suitable cooling agents. A gap similar to that between the liquid air and the liquid hydrogen region exists also between the latter and the region of liquid helium. The lowest temperature attainable with pumped-off solid hydrogen is still twice as high as the critical temperature of helium. Simon's ingenious idea was to substitute for the system gas-liquid a system of gaseous and absorbed helium, charcoal being used as adsorbent. This system has no critical point and the heat of desorption is large enough not only to cool the system from hydrogen temperatures to those of helium in a single step, but also to permit condensation of a fair amount of liquid helium. The desorption method cannot easily be adapted to a continuous process which is, however, no disadvantage in the case of a small-scale liquefier where only a few cubic centimetres of liquid helium are needed.

Another simple liquefaction unit for small-scale work has been designed by Ruhemann, using the Hampson-Linde method. In this case the trick is to substitute for the adjustable expansion valve a fixed constriction which greatly simplifies operation and construction. The latest liquefaction principle, Simon's expansion method which is reminiscent of Cailletet's adiabatic* expansion, is the simplest of all. A strong walled container which is precooled with solid hydrogen is filled with helium gas at 150 atmospheres pressure. Then the container is thermally isolated, a valve is opened, and the gas is allowed to escape into a gas holder. Thus a single 'stroke' of an expansion engine is performed at which, moreover, part of the gas is lost out of the 'cylinder'. At first sight it would appear that the liquefaction yield of this very uneconomical method may be poor. However, the astonishing fact is that after the expansion no less than 80% of the container volume is filled with liquid helium! This paradoxical result, too, is produced by the peculiar properties of substances near absolute zero. The heat capacity of the strong container (thermally a dead weight) is quite small, while it was overwhelming in Cailletet's experiment, and the high degree of filling is due to the anomalously low density of liquid helium. Actually, the gas under 150 atmospheres at hydrogen temperatures is much denser than the liquid at its boiling-point (4·2° K.).

The expansion method has been extensively used at the Clarendon Laboratory at Oxford. In fact, the first helium liquefaction in this country was carried out with a small liquefier of this type which the author installed at that laboratory early in 1933. Since then, at Oxford and elsewhere, a great number of these liquefiers have been constructed for measurements of electric, magnetic, thermal and optical properties and ranging in size from several hundred to four cubic centimetres expansion volume.

Sometimes the question is asked which of the various techniques is in the future likely to be adopted as the method of choice. It can be predicted with fair certainty that not one of these techniques is likely to supersede the others completely. Each has its advantages and its drawbacks. The Leyden technique provides ample amounts of liquid helium, but it requires costly installations and it does not make full use of the peculiar conditions near absolute zero. Kapitza's liquefier by-passes the hydrogen stage which not only makes for simplicity but also avoids the presence of liquid hydrogen which because of its inflammability is an unpleasant substance to work with. On the other hand the elimination of the hydrogen stage is a disadvantage when large capacities have to be cooled and also the construction of a Kapitza liquefier is fairly complicated, requiring a great deal of precision work. The small-scale technique is certainly very much cheaper than either of the other methods and it is extremely flexible. We shall see later that, owing to its peculiarities, it has led to the observation of phenomena which were swamped by the comparatively large heat influx into ordinary large-scale cryostats. Its disadvantage is the limited amount of liquid helium produced, and the need for a separate liquefier for each cryostat. Whereas with the large-scale techniques liquefaction is the responsibility of technicians, the liquefaction unit of the small-scale method has to be serviced and operated by the research worker, demanding experience and manual skill on his part.

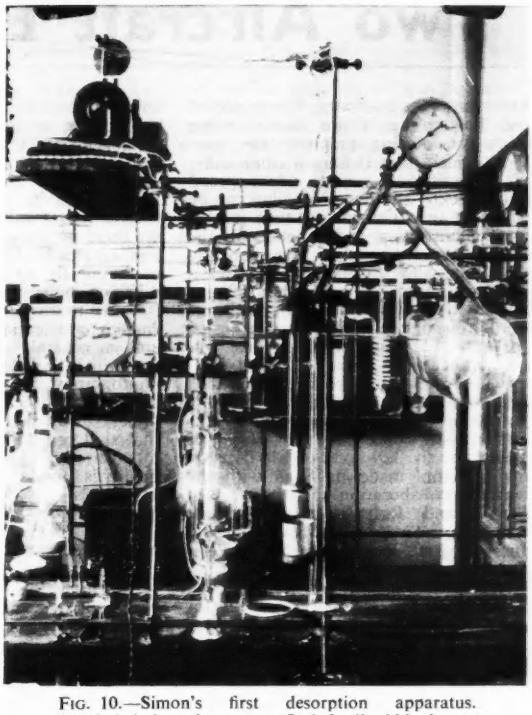


FIG. 10.—Simon's first desorption apparatus. (Exploded view; the vacuum flask for liquid hydrogen is removed).

Future development of cryogenic technique is likely to reduce more and more the differences between the various methods, trying to combine their advantages and to avoid their limitations. For instance, an expansion liquefier has been constructed which permits the successive introduction of a number of specimens without taking the apparatus to pieces or even warming it up. It thus

Cont. on p. 352

* *i.e.* without loss or gain of heat.

Two Aircraft Engineering Films

ANSWERING the questions 'how it works' and 'how to do it' are two very big fields for moving pictures: the ones about which most is known empirically. War intensified the need to induce special skills quickly, and nowadays films can be relied on to cut down the time needed for demonstration and practice on the actual apparatus or tools. Though nearly all training films are effective, some are a good deal more effective than others. The latter generally come from producers who have built their films on the logical anatomy of the subject under consideration, rather than a mere pictorial catalogue. Among such producers, the Shell Film Unit has for a long time held a position of distinction.

Clarity of exposition and clarity of picture are the key-notes of two films on fuel injectors made by Shell with the technical collaboration and assistance of BOAC and Rolls-Royce. They are entitled *A Single Point Fuel Injector* and *The Rolls-Royce S.U. Single Point Injection Pump—General Maintenance*. The first film, about the need for and principles of the injector, is intended for audiences with general knowledge of aircraft and no special knowledge of power units. The second is for the mechanics responsible for engine maintenance. Let it be said at once that the present reviewer, for whom the internal combustion engine is utterly devoid of both intellectual and emotional appeal, found the two films fascinating. They can be recommended for any film society or school audience.

Factors Controlling Fuel Flow

The first film begins with the carburettor in its simplest form, working on the rough-and-ready rule of 'the more air, the more fuel'. The need for more accurate fuel control is shown, and how it can be achieved by a pump forcing fuel at the needed rate into the engine. The factors that affect optimum rate of fuel flow are engine speed, atmospheric pressure, temperature and 'boost' (the few sentences needed to put into English the meaning of the last term unfortunately are omitted). The film then shows how appropriate devices are affected by these factors and, in turn, modify the pump delivery so that under all conditions it is an optimum.

The second film shows the injector in position; possible faults, their diagnosis and cure; and the procedures for removal and installation. This might seem rather dull for the non-specialist, but the sight of skilled men doing a job skilfully is always fascinating. Moreover, there is no hint of that stultifying dichotomy of the 'know how' from the 'know why' that infects levels higher than the workshop. Basic principles are as firmly embedded in this film as in the first and, as it shows some of the finer details, it can be properly regarded as a sequel, even for general audiences.

Pictorial clarity is remarkable. Almost all shots of machinery are close-ups from a few feet down to a few inches. Most of us find that in such cases the workman, the machinery, the camera, the cameraman, the lights and the shadows mix in a welter of inextricability. Here the camera and its adjuncts seem to have shrunk into Euclidean points; not only are there no disturbing shadows, but the lighting clearly differentiates the textures of the metals, so that recognition of the different components is immediate. This is no mean achievement. Aircraft engines are cactus-like agglomerations and, in general, machinery is very compact with little distinctions in tone. Colour photography is often quoted, especially in the United States, as the only satisfactory medium, but it seems from this that skill can do the job just as well in monochrome. The same high pictorial quality is found in the diagrams and shots of models.

Starring a Pump

Visually, as well as logically, the film is stolen by the swash-plate pump, the heart of the apparatus. Its *hula-hula* motion has the same hypnotic fascination as water flowing under bridges or a Veeder counter ticking over as well, of course, as the *hula-hula* itself. Most probably for the same reason. Anyone who tries to explain the three-dimensional motion of a swash-plate by word of mouth or by still diagrams will appreciate the immense strength of the moving picture in getting this concept across direct.

In a less carefully contrived film, minor criticism would be wasted. But here even minor blemishes show up against the general high quality. One regrets the solecism of *lbs.* as an abbreviation for *pounds*, and wonders whether US (spoken) is in any way superior to *unserviceable* or *out of order*. Admittedly, it is current in the shops and on the tarmac, but if the alphabetical eczema that currently afflicts the printed page is to infect common speech, a much clearer enunciation and more acute auditory discrimination than is usually found in unspecified parts of this country will be needed to avoid complete unintelligibility.

A more serious objection is that the word *meter* is used, as is the slovenly habit of 'engine-narks', in a way that clashes violently with all established usage. Moreover, there is no explicit explanation of this perversion, even though it is used in a vital part of the argument and is not to be found even in a modern technical dictionary. Any spectator unfamiliar with this esoteric jargon is likely to miss an important step while he puzzles out for himself the curious fact that *meter* is being used as a substitute for the verb *control*.

From the wider standpoint of educational technique, great interest and greater controversy will be aroused, among those concerned with such matters, by the section that attempts to materialise a mathematical formula into the interconnexions of mechanical devices. The reviewer, whose occupation has compelled many years of almost indecent familiarity with mathematical symbolism, found it unsatisfactory. The average audience may find it unintelligible. Starting from the abstract relations between the factors affecting fuel flow, expressed in the artificial language of symbols, it works down to concrete objects. This is a complete inversion of the proper order and, in this particular case, there seems no need to introduce the formula, a purely linguistic device, at all.

However, the fact that a serious attempt is made to deal with the most fundamental problem at all is encouraging and helpful. The presentation of general ideas in a medium that essentially deals with the particular lies near the heart of visual education. In mathematical films it comes up in most undiluted and intractable form, and the common confusion between the things talked about and the grammar of the language in which we talk about them cannot be slurred over. Any attempt to solve the problem, especially by producers who study presentation scientifically, is worth careful thought.

A New Kind of Education

This may seem a monstrous amount of sermon about what is, however well made, a small film about a small item in the ocean of modern technology. In fact, because such a theme on the ground level of education is based on fundamental principles, instead of mere description, we are entitled to suspect the beginnings of a new kind of higher education, that spreads from the everyday world upwards, instead of from the top downwards. All those familiar with much so-called research and development in this country, and elsewhere, come across the horrid blight of 'skill without understanding', the sure sign of intellectual decadence, that lies over British science and technology. That those responsible for what, up to now, has been treated as the lowest form of education, i.e. 'training', do not see it in that light, is most encouraging.

However, most audiences will be satisfied, in the first instance, to see two films that are instructive and a real pleasure to watch.

Both films were produced by Shell Film Unit, with Film Centre as production consultants. Director, John Shearman; Technical Adviser, Ivor Lusty, A.F.R.Ae.S. Available on loan (35 mm. and 16 mm.) from Shell Film Unit. Running times; 'A Single Point Fuel Injector', 22 minutes; 'The Rolls-Royce S.U. Single Point Injection Pump—General Maintenance,' 21 minutes.

ROBERT FAIRTHORNE

(This review is contributed by arrangement with the Scientific Film Association.)

The Bookshelf

Power. By Martin Ruhemann. (London, Sigma Books, 1946; pp. 123; 6*s*.)

THIS is a good-humoured book which I enjoyed immensely. It is charmingly written, and amusingly illustrated by Victor Reinganum's line-drawings. I should have preferred the photographic illustrations spread through the book, as the line-drawings are, rather than collected in one group at the end.

It consists of a very broad survey of the part which Work, Force, Power and Energy play in our daily lives. The language of the book is simple but very well chosen, and I cannot imagine a more 'readable' treatment of the subject. But the author, in his introduction, emphasises that he is writing not for scientists and engineers, but for machine operators, engine-drivers, car and bike owners and in fact the man in the street. I think that the book will be widely read by the first group and that they will enjoy it: so will the second group, but they will not understand it fully if it is their first book on the subject. For such a short book the range is so wide (covering even molecular structure of hydrocarbons and radioactivity) that many fundamental concepts are glossed over very rapidly: beginners will first need to get their definitions hammered in by drill examples from the more stodgy type of textbook. But having done that they may turn to the present volume to widen their outlook and understanding in a most entertaining way.

This is, in fact, the exact opposite of the old-fashioned stodgy textbook, and the author has shown how entertaining the subject can be made. I hope that many teachers and lecturers on the subject will cull ideas from here on language, humour, presentation and illustration.

S. J. BROOKFIELD

Frontiers of Astronomy. By David S. Evans. (London, Sigma Books, 1946; pp. 175; 6*s*.)

DR. EVANS has produced a very readable and interesting book which will appeal to a large number of readers in spite of the fact that he has little time for such a parochial affair as our solar system. His outlook is too comprehensive to waste time on such a rare occurrence as our planetary system, though it is true that he devotes one chapter to the subject in which descriptions of some of the planets are limited to a few lines.

Practically all the book is concerned with the stars, including our sun, and Dr. Evans is not only competent from the nature of his work to deal authoritatively with the subject, but his method of presentation cannot fail to arouse and increase the interest of readers. Chapter 2, 'The Astronomer's Weapons', describes different kinds of telescopes and also the main principles of the spectroscope—an indispensable equipment for present-day astronomers. Probably most readers will find the greatest interest in studying the subsequent chapters which describe the methods used for determining the temperatures, spectral types, distances, masses, etc., of the stars. Although the solar system itself is dealt with in a very summary fashion Dr. Evans has very wisely devoted a special chapter to the sun which is the most important star from our point of view and the easiest one to study. Some may object to the arrangement of Chapter 7, 'Oddities', which includes such a heterogeneous collection as white dwarfs, novae, variables, binaries, super-heavy giants, etc., Probably many who specialise on the study of variable stars would not feel disposed to include them under the heading of 'Oddities', but this is a matter of opinion. Chapter 8, 'Groups, Clusters and Collections', gives the most up-to-date description of the Galaxy and of the extra-galactic systems.

The book, which will be popular among a large number of general readers, is illustrated by 47 diagrams and 8 plates. Extensive captions accompany many of the diagrams and explain very clearly the particular matter under discussion. One word of criticism about the illustrations may not be out of place. Why are a few of them very much after the American style? Perhaps the reviewer is old-fashioned in his views but illustrations of this kind in scientific books, including popular books on science, always strike him as incongruous. M. DAVIDSON

An Introduction to Biochemistry. By William Robert Fearon. (London, William Heinemann, 1946; 3rd edition, pp. 569; 21*s*.)

THE appearance of a new edition of this book will be welcomed as six years have elapsed since the second edition, which was well received. All chapters have been revised, that on 'Nutrients' almost entirely rewritten, and a new one on 'Tissue Chemistry' added (but unfortunately this was missing from the imperfect review copy received). A wealth of information is supplied and, as before, biochemistry is approached through inorganic chemistry.

Before the next edition is written, it would appear desirable to decide the purpose of the book. An *Introduction* to biochemistry should be a carefully balanced up-to-date account of all aspects of the subject, with fundamentals emphasised and unessential details omitted for reasons of clarity, and the whole presented in an easily readable and attractive manner, preferably with appropriate illustrations, and of such a length that the student can hope to read, digest, and remember most of the book. Thus prepared, he would be in a position to study special topics in a *Reference Textbook* of biochemistry, which would supply greater detail and, most important, numerous references to original papers and recent reviews. Professor Fearon's book is in danger of falling between these two stools. The first edition contained 313 pages, the second 475, and the present one, 569, and with such vigorous growth it will soon be difficult for the beginner to see the wood for the trees. If the book is to remain an introduction, some fairly drastic pruning will have to be done, not only to enable the student to see more clearly the really important basic ideas, but also to make room for certain topics at present omitted, as chemotherapy, bacterial metabolism, and growth factor antagonism. Better balance would result if the considerable contribution to biochemistry made by the synthetical organic chemist was not almost ignored; there is nothing, for example, in the chapter on amino-acids to indicate to the student that any of these have ever been made in the laboratory. More emphasis might be placed on the experimental background and techniques of biochemistry, as biological assay, manometry, methods of isolation and purification, etc. It is strange that no example of the graphical representation of experimental data is given, since, for instance, Hopkins's results on feeding rats with and without vitamins are so striking when shown as growth curves that the student is unlikely to misunderstand or forget them. The inclusion of such curves, more diagrams and sketches and some illustrations would greatly increase the clarity and attractiveness of the book, and would be well worth the extra cost.

Minor blemishes of various kinds are not infrequent. Some are slips missed in proof-reading (as 'alimentary tract'), some due to oversights in revision (e.g. the cyclic tetranucleotide structure mentioned for yeast nucleic acid was abandoned at least five years ago), some arithmetical (e.g. '27 equals 148') and some due to incorrect statements (e.g. 'only one of the 8 isomers of inositol is optically inactive'). B. A. KILBY

The Mid-Twentieth Century Atom. By Martin Davidson. (London, Hutchinson's Scientific and Technical Publications, 1946; 8*s*. 6*d*.)

THIS book is intended for the intelligent layman and aims at giving a general understanding of atomic theory. A series of chapters present evidence leading to the modern conception of atomic structure, both of the nucleus and of the shells of electrons round it. There are sections on radioactivity and on solar and stellar energy, and finally an addendum on atomic energy together with appendices on subjects slightly more advanced than those dealt with in the main text.

In spite of the author's explanation in the preface the title of the book is not well chosen. Several factual errors have crept into those parts dealing with chemistry, mainly through over-simplification of theory. The most serious criticism which must be made, however, arises from the fact that the information presented is somewhat disjointed, and it is doubtful whether a *clear* picture of atomic structure is conveyed to the reader.

The best part of the book is that dealing with solar and stellar energy, where in a few pages a considerable amount of interesting material is contained.

W. J. ARROL

Far and Near

U.S. Atomic Commission

ON October 28 the members of the United States Atomic Commission were named. Head of the commission is Mr. David E. Lilienthal, formerly director of the Tennessee Valley Authority and chairman of the committee which produced the plan for international atomic energy control on which the Baruch proposals were based. The other members are: Dr. R. F. Bacher, Cornell University physicist who worked on the atomic bomb project; Mr. S. T. Pike, Mr. L. T. Strauss and Mr. W. W. Waymack.

The commission will take over all atomic energy properties and the organisation of the Manhattan project. The President said he assumed that there would be a transition period of several months, during which the War Department would continue to be responsible for the Manhattan project.

Russia's Budget for Science

EXPENDITURE on science in the Russian budget for 1946 was announced last month. It amounts to 6·3 billion roubles, three times the sum spent in 1945. The figure represents more than 2% of the national income of which about 23% goes to defence.

Wells Memorial Meeting

ABOUT 600 people attended a memorial meeting for H. G. Wells held at the Royal Institution on October 20. It was arranged by the British Association, the Society of Authors, P.E.N. (English Centre) and the National Book League. The speakers were Lord Beveridge, Sir Richard Gregory, Professor G. D. H. Cole, Mr. J. B. Priestley and Mr. David Low. A reading from Wells's *First and Last Things* concluded the meeting.

British Scientific Service in U.S.A.

SIR ALWYN CROW has been appointed head of the scientific and technical services of the British Supply Office in Washington. He will be responsible for maintaining liaison with the United States authorities on all scientific matters (other than atomic energy) for which the Ministry of Supply is responsible.

Chatham House Atomic Committee

THE Royal Institute of International Affairs has set up a committee on atomic energy, under the chairmanship of Sir Henry Dale; this atomic committee will collaborate with the American Committee of the Carnegie Endowment.

Radar and Atomic Films

PUBLIC interest in atomic energy and radar will be further stimulated by the appearance of various films now in production in Britain and elsewhere. In this country, Film Centre is advising on a documentary film on atomic energy; the full-length feature film about Radar, *School for Secrets*, directed by Peter Ustinov and recently completed by Two Cities Films at Denham, has not had its London premiere. A five-reel film *From RDF to Radar* has been made by T.R.E., Malvern—a filmic record of the growth of radar in the years before and during the war; it is intended mainly for internal distribution in Government departments. In America, M.G.M. are making *The Beginning or the End?*, a feature film of over two hours' duration, with a large cast; this will first be shown in this country in March or April next. The March of Time film, *Atomic Power*, has already been released.

Christmas Lectures at Royal Institution

THE 117th course of six lectures for a juvenile auditory will be given this year by Professor H. Hartridge, F.R.S., on the theme "Colours and how we see them". The first lecture will be given on December 28. Subscriptions for these lectures are: children (10-17), half a guinea; adults, one guinea.

A Scientific Film Journal

THE London Scientific Film Society has just produced the first number of its journal entitled *The Scientific Film*. The issue includes articles by Dr. E. M. Crook, Val Walker, John Shearman and William E. Dick. The journal is offering prizes for the best reviews of films shown by the Society, and details of the competition are published in the first number. The journal is published at 6*d*. from 34 Soho Square, London, W.1.

Coal Industry Research

SIR CHARLES ELLIS, scientific director of the National Coal Board said last month that nationalisation would afford far better opportunities for organising the scientific work of the industry. He looked forward with confidence to the future, and he was sure the scientific service of the National Coal Board would meet its responsibilities. Each of the eight divisions under the board would be allotted a divisional scientific organisation under a divisional chief scientist. He would have a central divisional laboratory, and one in each area and in some cases in sub-areas.

Centenary of Anaesthesia

THE centenary of the first surgical operation under general anaesthesia was celebrated in London on October 16 at a special meeting of the History of Medicine section of the Royal Society of Medicine.

Two Museums Reopen

PARTS of the Natural History Museum, South Kensington, are now open to the public. The Horniman Museum has also been repaired and is open 10.30 a.m.-6 p.m. daily, 2-6 p.m. on Sundays.

Fundamental Research in Industry

IMPERIAL CHEMICAL INDUSTRIES have leased the house and laboratories at The Frythe, Welwyn, Herts, for long-term general and academic research in branches of biological, chemical, and physical science. Among the subjects to be studied are the antibiotic products of moulds, kinetics of continuous chemical reactions and the deformation of materials under high stresses of short duration. Work will also be done on the design of industrial instruments and on industrial toxicology.

The new laboratories will eventually house twenty or more senior research workers, with assistants and administrative staff. Some of the staff have already been recruited, but have hitherto been scattered in various localities whilst engaged on war-work.

The premises at The Frythe are intended as temporary accommodation until a site at Butterwick Wood, near St. Albans, which was originally selected, can be developed.

The activities of the Butterwick Research Laboratories will be completely independent of all other I.C.I. research departments, which will continue to be concerned with more specifically industrial problems.

Wealden Natural History

THE natural history of the Tunbridge Wells district is described in detail in the volume *Royal Tunbridge Wells*, which the S.E. Union of Scientific Societies prepared for its jubilee congress this year and which is published by the Courier Printing and Publishing Co. Ltd., Tunbridge Wells, at five shillings. Wealden geology is also described, and other chapters deal with local history and pre-history. The volume was edited by Dr. J. C. M. Given.

Atomic Ship Propulsion

THE U.S. Navy's Office of Naval Research is embarking on a wide programme of fundamental research, with particular emphasis on the development of atomic energy for ship propulsion. The researches will be conducted at eighty-one universities throughout the United States and also at private and industrial research laboratories. Naval research will be conducted in conjunction with the Joint Research and Development Board, on which the War and Navy Departments are represented and which has Dr. Vannevar Bush as director.

UNESCO and Scientific Unions

A DRAFT agreement has been drawn up for the establishment of close co-operation between the United Nations Educational, Scientific, and Cultural Organisation and the International Council of Scientific Unions. This will be submitted to the inaugural meeting of the permanent organisation of UNESCO at the end of this year. By the terms of this agreement UNESCO recognises the ICSU as the principal co-ordinating and representative body of international organisations of science, while the latter recognises UNESCO as the principal agency of the United Nations in the field of international scientific relations.

Night Sky in December

The Moon.—Full moon occurs on December 8d 17h 52m, U.T., and new moon on December 23d 13h 06m. The following conjunctions take place:

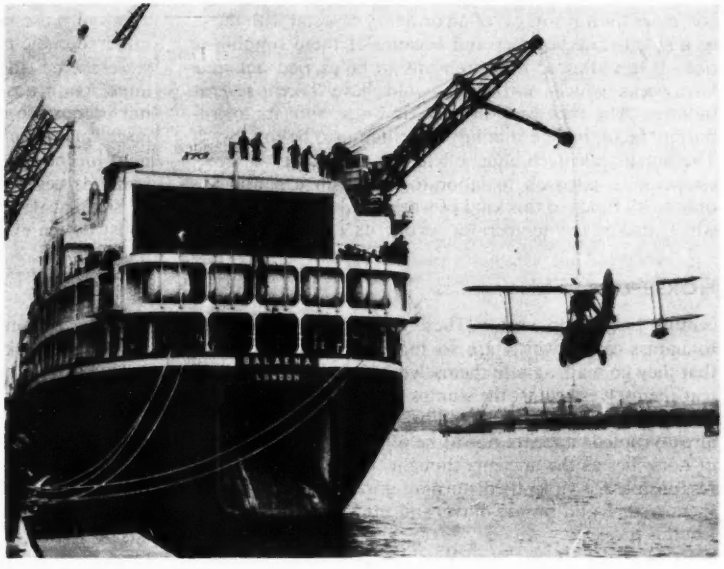
December				
12d 04h	Saturn in conjunction with the moon,	Saturn	4°	S.
19d 21h	Jupiter ,,	Jupiter	1	S.
20d 02h	Venus ,,	Venus	1	N.
21d 22h	Mercury ,,	Mercury	0·8	N.

Eclipse of the Moon.—There will be a total eclipse of the moon on December 8, visible at Greenwich. The circumstances of the eclipse are as follows:

Moon enters penumbra	15h 11.8m
Moon enters umbra	16h 10.2m
Total eclipse begins	17h 18.8m
Middle of eclipse	17h 48.0m
Total eclipse ends	18h 17.2m
Moon leaves umbra	19h 25.8m
Moon leaves penumbra	20h 24.2m

The Planets.—Mercury is a morning star, rising at 6h on December 1 and 7h 20m on December 31. It is stationary on December 1 and attains its greatest westerly elongation on December 9. Venus can be seen in the morning hours, rising at 5h 54m, 4h 50m and 4h 23m at the beginning, middle and end of the month respectively. The planet appears bright, her stellar magnitude varying from −4·0 to −4·3 during the month. Mars is too close to the sun for favourable observation. Jupiter is a morning star and rises at 5h 28m, 4h 50m and 4h 05m at the beginning, middle and end of the month respectively. The stellar magnitude of Jupiter is about −1·3 in December. Saturn can be seen throughout the greater part of the night, rising at 20h 28m, 19h 30m, and 18h 21m at the beginning, middle and end of the month respectively. Saturn does not appear as bright as Jupiter, the stellar magnitude being about 0·1 during the month. Its distance from the earth on December 1 and 31 is 797 and 765 million miles respectively.

Winter solstice occurs on December 22d 11h. On this day sunrise and sunset take place at 8h 04m and 15h 53m respectively in the latitude of Greenwich.



This 15,000 ton whaling-factory ship, *Balaena*, sailed for the Antarctic last month. On board were three scientists of the Department of Scientific and Industrial Research, Dr. R. A. M. Case, Dr. Whittle and Mr. Ireland. In addition the expedition has two chemists of the United Whalers company and a biologist from the *Discovery* Committee. The D.S.I.R. is interested in the possibility of using lean whale meat, frozen or dehydrated, for human food. The ship is equipped with radar direction-finding devices. Three amphibian Walrus aircraft are carried and will be used for spotting whales. The catapult used for launching these planes was formerly installed in H.M.S. *Pegasus*, the Fleet Air Arm training ship.

History of Stains and Microscopy

A USEFUL history of the use of colouring agents (not only dyes but also such substances as Schulze's chlor-zinc-iodine) in biological investigations has been written by Dr. John R. Baker for the Quekett Microscopical Club. How early such agents were added to the microscopist's armoury is illustrated by the following quotation from the monograph: "Our knowledge of the earliest example of the use of dyeing in biological micro-technique is due to the historical studies of F. T. Lewis of Harvard Medical School, who showed that the discovery was made by Leeuwenhoek; the latter was engaged in comparing the muscle fibres of a fat and a lean cow. He found that his sections were too transparent for observation and therefore soaked them in Crocus (no doubt saffron) macerated in wine. He then subjected his preparation to microscopical examination . . . He wrote an account of his investigations on 21 August, 1714, in the form of a letter to the Royal Society." But no one followed Leeuwenhoek's method; it remained for dyeing to be rediscovered as a result of the use of coloured injections intended to show the course of the vessels of plants. Uncertain claims being ignored, the honour for first using such dyeing to determine plant structure should be attributed to Reichel (1758); twelve years later John Hill, an Englishman, used a similar technique, steeping the 'rind' of trees in a solution of cochineal and, alternatively, in lead acetate followed by a solution of calcium oxide and orpiment, the latter method resulting in a brown coloration in the cell walls. The use of dyes by plant anatomists continued, says Dr. Baker, in a desultory way but did not become a standard part of microtechnique; the whole subject of dyeing required to be rediscovered. From 1848 onwards, dyeing was repeatedly rediscovered, and in a table in the monograph which sets out neatly the dates of the most important discoveries it is seen that the period 1848–58 was rich in fruitful advances.

The injection of coloured fluids into blood vessels to facilitate naked-eye observations is much older than non-vital dyeing. It was first done by Eustachi in the sixteenth century; in the next century Malpighi used ink for this purpose and Vieussens tried wine coloured with saffron.

The earliest attempts at staining living tissue were made as long ago as 1744 when Trembley fed *Hydra* on a wide variety of coloured organisms; for instance, he made this animal dark by feeding it on small tadpoles and a black planarian, and green by giving it aphids. He also tried to get *Hydra* to take minute pieces of the coloured petals of flowers with the object of getting the plant pigment transferred to the *Hydra* but these were either refused or rejected. He experimented with infusions of delphinium and marigold flowers, probably the first attempt at straightforward vital colouring; the *Hydra*, however, died under such treatment, and it was 134 years before any such method was again described. In 1878 Brandt used the dye Bismarck Brown to colour fat and other granules in sun animalcules and three years later Certes coloured a ciliate with quinoleine blue.

The development of colouring by phagocytosis, histochemical colour tests and impregnation with opaque substances are also discussed in this monograph, which is entitled *The Discovery of the Uses of Colouring Agents in Biological Micro-Technique* and published for the Quekett Microscopical Club by Williams and Norgate.

LOW-TEMPERATURE PHYSICS—*Continued from p. 347*

combines the advantages of an ordinary cryostat with those of a small-scale liquefier and because of these simplifications it has allowed measurements to be carried out in a few weeks which otherwise would have taken several months. The type and amount of work, too, is an important factor in determining the technique to be employed. The small-scale technique offers the possibility of low-temperature research to laboratories which can allocate only small funds to this kind of work, while any laboratory which makes low-temperature work its main object will eventually use equipment which provides at least several hundred cubic centimetres of liquid helium. It should be remembered in this connexion that small-scale helium liquefaction was developed at a time when helium gas was not procurable in quantity. Today helium is available in large quantities from natural gas and is the least costly item on the bill of a low-temperature laboratory, but the methods developed and the experience gained in the use of small-scale technique are likely to modify greatly the construction even of large cryostats.

HORSEFLIES—*Continued from p. 331*

century Lady Fenn wrote: "These flies are seen in summer to harass cattle, which are so molested by their stings that they go mad, agitate themselves, run down precipices, tear themselves against the stumps of trees." The peculiar phenomenon known as 'gadding' in cattle, as we have already noted, appears not to be attributable to the bites of horseflies as the ancients thought, but the flies are still responsible for violently disturbing grazing herds, keeping them restless and on the move, and preventing them from feeding properly.

Early settlers in the New World found the same situation there. One report by C. B. Philip (1931) records that "moose and deer lose all fear of man and plunge into rivers and lakes to escape (the horseflies') attacks: they soon become very poor, as they have no rest to feed except at night." Similar migrations of animals have been noted in the Sudan, and even in the Scottish Highlands wild deer have been seen to be driven up to the highest ground by attacks of horseflies. A report by Major Fraser, who served in N. Russia in 1919, has been much quoted in this connexion. He stated that agricultural work had to be almost entirely suspended during the day and humans as well as animals spent days indoors. More than a hundred horseflies could be counted on one person at the same moment.

Estimates have been made of the possible loss of blood by an animal exposed to the attacks of horseflies throughout a summer day in a badly infested area. Philip reaches a figure of 300 cc., or about half a pint per day, not including blood which oozes from the wound and is often lapped by other, non-biting flies.

Direct protection against horseflies by the use of chemical repellants has had little success. The Russians, as noted by Fraser, smeared their horses with paraffin, and the Americans have tried numerous formulae. Tabanids, however, are tough customers, and any preparation powerful enough to discourage them is inclined to be equally objectionable to the user. Certainly nothing that a human being would tolerate has been devised.

In a badly infested area the best remedy is a long-term policy of drainage aimed at removing suitable breeding-places, while rapid fluctuations of the water-level in ponds and streams during the summer will help by drowning pupae which are lying just below the surface of the soil. The best direct assistance that can be given to stock is to provide shade, such as a darkened shed to which they can retreat. Some farmers place a hanging sack in the doorway to help in brushing off any flies clinging to the animal. Tabanidae are great lovers of sunlight, and will not follow stock into a darkened interior.

This love of heat is shown by the peculiar way in which horseflies follow motor cars. Not only do they like to follow a moving vehicle, but when it is stationary they will settle on the radiator and tyres.

Tabanids do not appear to carry disease actively, in the way that a mosquito carries malaria, where the parasite undergoes a definite part of its life cycle inside the fly. It has been shown, however, that they can take more than one meal of blood, each being followed by a separate act of oviposition, and so they can act as passive carriers of disease from one victim to another. In West Africa the nematode worm causing 'Calabar swellings' is carried by two species of *Chrysops*, and in America yet another *Chrysops* carries tularaemia, or deerfly fever from jack rabbits to man.

The most important horsefly-borne disease is 'surra', or 'El-Debab', a trypanosome disease affecting horses, donkeys, mules, camels, cattle, elephants, and dogs. H. C. Efflatoun quotes a report that 80% of the camels passing through one particular region of Upper Egypt became infected, and that on one frontier station 5% of the camels were lost annually through this disease. It is known from Africa to the Far East, and in recent years the Russians have given a great deal of study to it, including much work on the Tabanidae of their Central Asiatic Republics.

One final note about other victims of Tabanids. Besides man and domestic animals, horseflies are known to attack wild ungulates (deer, antelope, etc.), rabbits, squirrels, rats, and even such out-of-the-way victims as tortoises and crocodiles.

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